UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDY TO DETERMINE A SEDIMENT CONTROL ARRANGEMENT FOR SOCORRO MAIN CANAL HEADWORKS--SAN ACACIA DIVERSION DAM MIDDLE RIO GRANDE PROJECT, NEW MEXICO

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Fifty-nine tests requiring over 1, 500 hours of model operation were required to obtain sufficient model information to complete this study. The tests were conducted during 1959 and 1960 by Phillip F. Enger, Russell A. Dodge, Jr., and Eugene R. Zeigler of the Hydraulic Laboratory staff. Several engineers on training assignments in the Hydraulic Laboratory helped to collect data. These included: Jimmy Joe Straughn, Russel Hathaway, Jr., Richard L. Wight, Merlin C. Williams, and Thomas K. Underbrink. Richard L. Wight was especially helpful in organizing data from several tests. The study was under the supervision of E. J. Carlson.

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SUMMARY

The purpose of the study was to determine a satisfactory method of reducing the quantity of coarse sediments entering the Socorro Main Canal headworks located at San Acacia Diversion Dam on the Rio Grande approximately 60 miles south of Albuquerque, New Mexico. Tests were made on a movable bed hydraulic model, and a partial verification with the prototype was obtained. Tests were conducted with river discharges of 8, 760, 2, 270, 1, 700, and 680 cfs (cubic feet per second). Various methods of controlling sediment intake were tested and three methods were found which resulted in satisfactory improvement. The three methods were (1) bottom guide vanes with the canal headworks in the upstream location, (2) a siphon to convey water across the low-flow channel when the canal headworks was moved to the downstream location in the sluiceway, and (3) a flume to convey water across the low-flow canal when the canal headworks was moved to its previous downstream location in the sluiceway.

Considering all the factors involved, it was recommended that (3) be adopted, i.e., that the canal headworks be moved to the downstream location and a flume be constructed across the low-flow channel. This arrangement in the model resulted in a reduction of approximately 90 percent in coarse sediments entering the canal when the river was discharging a total of 680 cfs; 480 cfs being diverted to the low-flow channel and 200 cfs being diverted to Socorro Main Canal.

INTRODUCTION

San Acacia Diversion Dam is located on the Rio Grande approximately 60 miles south of Albuquerque, New Mexico, Figure 1. The dam was built in 1936 by the Middle Rio Grande Conservancy District to divert water into Socorro Main Canal for irrigation purposes. The dam, Figure 2a, contains 29 river gates 20 feet wide and 7.5 feet high. When these gates are closed they create a backwater from which Socorro Main Canal flows are diverted. The canal headworks of the original dam was located in a sluiceway placed near the right bank of the river, Figure 2a (plan before 1958). The maximum discharge for which the canal was designed was 265 cfs.

In the winter of 1957-58, the Bureau of Reclamation modified the right bank diversion structure, Figure 2b. A low-flow channel was constructed parallel to the river channel to salvage water by concentrating the flow from the wide meandering river into a narrow, straight, and relatively watertight channel. This channel, capacity 2,000 cfs, saves considerable water in the approximate 60 miles between San Acacia Diversion Dam and Elephant Butte Reservoir. The reduction in seepage and evaporation losses, the increased velocities in the channel and the increased salvage of drainage water have resulted in appreciably more water reaching Elephant Butte Reservoir.

The low-flow channel headworks was placed on the right riverbank with headworks centerline approximately 135 feet upstream from San Acacia Diversion Dam, Figure 2b. The Socorro Main Canal headworks was relocated approximately 120 feet upstream from the low-flow channel headworks. The existing canal headworks located downstream from the dam was left intact and used to divert water into the low-flow channel. No provisions to eliminate sediment from Socorro Main Canal headworks were made. The low-flow channel was designed to carry the sediment which entered the channel headworks.

The canal headworks was opened March 7, 1958, and discharge in the river and canal was relatively constant until April 13. The river then began to rise, and a resulting increase in sediment load occurred. Sediment deposits in the first 1-1/2 miles of canal gradually increased, with a resulting decrease in canal capacity until on May 23, only 35 cfs could be discharged through the canal. The canal was closed and cleaned on May 24 and 25. After the canal was reopened on May 26, sediment deposition continued until the river stage began to recede, at which time the sediment deposits were gradually eroded from the upstream portion of the canal. During the period May 26 to June 3, bed elevations were measured in the canal, and discharge and sediment data were obtained. The average discharge in the river during this period was 8,760 cfs and the average canal discharge 174 cfs.

To help determine a satisfactory method of reducing the amount of sediment entering the canal headworks, a hydraulic model study was conducted. A movable bed hydraulic model was constructed and tested to verify model performance against known prototype performance. After verification, various methods of controlling sediment movement were investigated, and a satisfactory method of improving sediment intake conditions at Socorro Main Canal headworks was determined. The recommended design is shown in Figure 2c.

CONSTRUCTION AND OPERATION OF MODEL

The model was constructed to a 1:20 scale, Figures 3 and 4a. The right side of the diversion dam containing 12 river bays with gates, the sluiceway area, and a movable bed representing the river for approximately 600 feet upstream from the diversion dam were reproduced. Approximately 500 feet of canal and 400 feet of low-flow channel were represented in the model. Prototype topography included the remains of a cofferdam which forms an island in the river approximately 70 feet offshore from the low-flow channel headworks and bank protrusions approximately 30 feet upstream and downstream from the canal headworks. In the model these features were constructed so they could be rapidly removed or their position changed; they are visible in Figure 4a. The model box was constructed of wood and lined with sheet metal. Major features such as river gates, conduits, slide gates, and sampling equipment were generally constructed of sheet metal. Treated wood was used for piers between radial gates, and portions of the canal and low-flow channel were constructed of metal lath covered with concrete. For the tests on the inverted siphon located beneath the low-flow channel, both the siphon and low-flow channel were constructed of heavy clear plastic to allow flow and sediment conditions in the siphon to be observed.

Discharges and water surface elevations for the canal and low-flow channel were maintained by slide gates at the headworks and downstream end. Backwater was maintained on the radial river gates by using slide gates constructed for the purpose downstream from the diversion dam, Figures 3 and 4.

A fine sand of near uniform size gradation, Figure 5, was used to form the movable bed in the model. The average diameter of the model sediment was approximately 0.2 mm (millimeter). Figure 5 shows gradation analyses curves of the model and prototype sediments, and Figure 6 shows the settling velocities for these sediments.

Two pumps were used to supply water and sediment to the model. No. 1 pump positioned at the downstream end of the model, Figure 3, carried sediment-laden water to the upstream end of the model for recirculation. No. 2 pump drew clear water from a laboratory reservoir, and supplied a small amount of water to replace sampling losses. This water was introduced into the upstream end of the model and maintained a constant head on pump No. 1. Excess water discharged over a weir at the downstream end of the model.

Samples of water and sediment discharging from the canal, low-flow channel, sluiceway and river gates were obtained by passing a hand-operated sediment sampler through the discharging water, Figure 4b. The samples were conducted to volumetric collectors calibrated to indicate the amount of water and sediment in liters. After the sediment settled in small funnels at the bottom of the collectors, its volume was determined. By these means the concentrations of sediment passing through the parts of the model could be readily determined at any time during a test. Data were obtained periodically throughout each test. To account for sediment which had passed through the intakes but had not been accounted for in the sampling process, the amount of sediment which had deposited in the canal and low-flow channel was also measured. The sediment concentration was therefore based on the discharge and the average sediment concentrations which passed through various parts of the model, taking into account the amount of sediment deposited.

For all tests, the water surface elevation just upstream from the dam was held near elevation 4668.7 feet, the normal water surface elevation in the prototype structure. Tailwater elevations below the radial river gates for various discharges were adjusted to correspond to average elevations obtained from U. S. Geological Survey measurements made in the river for similar discharges, Figure 7. The canal and low-flow channel intake gates were calibrated while holding the water surface upstream from the dam at the normal elevation of 4668.7 feet, and maintaining the canal and low-flow channel water surface at the calculated elevation for the discharge. Discharge conditions similar to those that occurred at the prototype structure between May 26 and June 3, 1958, were used as standard discharges for most tests. These conditions were a river discharge of 8,760 cfs, with 8,586 cfs continuing down the river and 174 cfs diverted to Socorro Main Canal.

When contours of the movable bed configuration at the end of a test were desired, elevations were obtained with an engineer's level and rod and appropriate plots made. To help evaluate test results, both black and white and color photographs of sediment deposits and bed conditions were obtained for each test.

THE INVESTIGATION

Control Tests--Tests 1 Through 4

The first model tests (Tests 1 through 4) were made to establish sediment concentration ratios for comparison with later tests, to verify the model, and to determine the effects of minor changes in topography near the headworks. These tests were made with the canal headworks, low-flow channel headworks and river gates located according to the 1958 prototype conditions. For all tests the standard discharge was used, and samples were taken periodically during the test. Table 1 summarizes the tests, and a more detailed description of each test follows:

Table 1

Test No.	Total hours test was conducted	Average concentration of sediment in the river, ppm	Average concentration of sediment entering canal headworks, ppm	Concentration ratio*, C_c/C_{rus}
1	8.8	338	896	2.65
2	52.5	407	1,178	2.89
3	36.0	313	620	1.98
4	28.7	364	1,971	5.41

*The concentration of sediment entering the headworks divided by the concentration of sediment in the river.

1958 Topography--Test 1

Model topography was similar to that existing at the prototype structure in 1958. This included the remains of the cofferdam and bank protrusions both upstream and downstream from the canal headworks, Figures 3 and 4a. Sediment concentration data, obtained from sampling the river and the canal, indicated a bedload sediment concentration of approximately 338 ppm (parts per million by weight) moving in the river upstream from the headworks, and a concentration of 896 ppm passing through the canal headworks. Data were obtained on the rate of sediment deposition in the canal, and this rate was compared to the rate of deposition which occurred in the prototype during 1958, when operating conditions similar to those used in the model occurred. Although a considerable scatter of data resulted, Figure 8, the most probable time scale between the model and prototype was indicated to be $(L_r)^{0.868}$ (or approximately 1:13.5), where L_r is a ratio of a length in the model to a corresponding length in the prototype. This indicates that 1 hour of operation in the model produced a volume of deposits in the canal approximately equivalent to that for 13.5 hours of operation in the prototype.

The time scale ratio was determined using the standard test discharge, and an average sediment concentration in the river of 338 ppm. Variations in the discharge and sediment concentrations would, no doubt, result in a change of the time ratio. However, as standard discharges were maintained for most tests, and an attempt was made to maintain the sediment concentration near 340 ppm, the time ratio 1:13.5 was used for analyzing data. When reporting times, model time is always given unless otherwise stated. No 1958 riverbed topography was available for comparison with the model topography used in Test 1. However, riverbed topography was available which represented conditions as of the latter part of July 1959. At this time, flash flows from the tributaries, Rio Puerco and Rio Salado, produced a maximum river discharge of 4,840 cfs. Of this amount, 1,350 cfs was diverted to the low-flow channel, 175 to 190 cfs was diverted to Socorro Main Canal and 3,300 cfs continued down the river. Although these flow conditions are for discharges different than those used for Test 1, the bank protrusions and island were present in both model and prototype, and the results are comparable to some degree. Bed contours for the two conditions are shown in Figure 9.

Test 1 was used as a control test to which tests of various sediment control arrangements were compared. The effectiveness of the various sediment control arrangements was compared on the basis of the ratio of the concentration of sediment entering the canal headworks to that moving in the river upstream from the headworks. For Test 1 the ratio was:

$$\frac{C_c}{C_{rus}} = 2.65$$

where

C_c = concentration in parts per million by weight of sediment in water entering the canal headgate

C_{rus} = concentration in parts per million by weight of sediment in the river water upstream from the canal headworks

Concentration ratios were determined from the average of numerous sampler operations after the model had been operated for a number of days to establish equilibrium.

Equilibrium occurs when the total amount of sediment discharged from the model is equal to the total amount being introduced at the upstream end of the model.

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Equilibrium occurs when the total amount of sediment discharged from the model is equal to the total amount being introduced at the upstream end of the model.

As sediment deposits decreased the effective cross section of the canal, the discharge decreased. For Test 1, the average discharge decreased from the initial 174 cfs to 96 cfs, about 45 percent, in 8.8 hours. During this period the water surface in the canal was held at the normal water surface elevation for 174 cfs. If the canal water surface had been allowed to vary, the decrease in discharge would also have varied. A photograph showing the extensive sediment deposits in the canal after Test 1 is shown in Figure 10a.

From the results of Test 1, it was concluded that the time ratio between model and prototype was equal to 1:13.5, and that the model concentration ratio of 2.65 was comparable to the unsatisfactory prototype conditions which occurred in 1958.

Local Topography Effects--Tests 2, 3, and 4

Test 2.--To help determine the effects of local topography on the amount of sediment entering the canal headworks, the island which was a remaining portion of the cofferdam, and the protrusion upstream from the canal headworks were removed for Test 2. The standard discharge was set and a 23.5-hour test was conducted. Sediment deposits in the canal resulted in the canal discharge decreasing from the initial 174 to 54 cfs, about 69 percent. As this appeared to be a more adverse condition than Test 1, another test was conducted to check the results. During the second test of 29 hours the canal discharge decreased to 59 cfs. The average concentration ratio resulting from the two tests was 2.89.

It was concluded that removal of both the cofferdam and the upstream protrusion without additional remedial measures would result in continued unsatisfactory conditions in the prototype.

Test 3.--To determine the effect of only the cofferdam island on the sediment concentrations entering the canal headworks, the upstream protrusion was replaced in the model, and a test was conducted without the island in place. The standard discharge was set, and two runs were made. In the first test of 28.9 hours, canal discharge decreased 56 percent. In the second test of 7.1 hours, canal discharge decreased 29 percent. The average resulting concentration ratio was 1.98.

Although a decrease in the amount of sediment entering the canal was indicated, it was concluded that these amounts of sediments were still too high, and that a more satisfactory concentration ratio should be obtained.

Test 4.--To determine if cleaning the area in front of the headworks would improve sediment intake conditions in the canal, the cofferdam island and the protrusions upstream and downstream from the canal headworks were removed for Test 4. The standard discharge was set and two runs were conducted. In the first run of 22.0 hours, canal discharge decreased 49 percent and in the second run of 6.7 hours, canal discharge decreased 27 percent. The decreases were due to heavy sediment deposits in the canal; the concentration ratio was 5.41.

Periodically, during Tests 1 through 4, cross sections of sediment deposits in the canal were obtained and the quantity of sediment deposited in the canal was calculated. Curves of time versus sediment accumulation were plotted, as was the decrease in canal discharge. These data showed that the sediment intake into Socorro Main Canal model was high, as it was in the prototype, and the headworks arrangement was considered to be unsatisfactory. Testing was continued to improve the arrangement.

Skimming Weir and Guide Wall Arrangement Tests 5, 6, 7, and 8

The skimming weir and guide wall arrangement shown in Figure 11 was constructed in the model for Tests 5, 6, 7, and 8. The arrangement consisted of a solid floor at elevation 4661.0 feet which extended approximately 98 feet into the river and 202 feet upstream from the dam axis. A guide wall with top elevation at 4670 feet was placed parallel to the right riverbank and approximately 98 feet from the bank. A curved skimming weir with top elevation at 4665 feet was placed parallel to the right riverbank and approximately 32 feet from the bank. The skimming weir curved into the right bank approximately 40 feet above the canal headworks. For all four tests, the standard discharges of 8,760 cfs in the river, and 174 cfs in the canal were set initially.

Uniform Gate Opening--Test 5

For Test 5, all river and sluice gates were opened equally, and two runs were made. During the first run of 43.8 hours, discharge in the canal decreased 25 percent. During the second run of 6.7 hours, the canal discharge decreased 7 percent. The resulting average concentration ratio was 2.99.

Variable Gate Openings--Tests 6, 7, and 8

Test 6.--For Test 6, all sluice gates were fully opened, the gates between the skimming weir and guide wall were maintained at the same opening as for Test 5, and the remaining river gates were adjusted to maintain the normal water surface elevation in the forebay. Two runs were conducted. In the first 3-hour run, discharge in the canal decreased 3 percent, and in the second 3.5-hour run, the discharge decreased 10 percent. The resulting average concentration ratio was 1.57.

Test 7.--All gates inside the guide wall were fully opened, and the remaining river gates were adjusted to maintain the desired water surface elevation upstream from the dam. Two runs of 1 and 2.5 hours were conducted. The average discharge decrease in the canal was 9 percent and the average concentration ratio was 1.40.

Test 8.--For Test 8, the sluice gates were fully opened, the gates between the skimming weir and guide wall were closed, and the remaining river gates were adjusted to maintain the normal water surface elevation upstream from the dam. During the first run of 21.8 hours, canal discharge decreased from 174 to 148 cfs, about 15 percent; and during the second run of 7.2 hours, the discharge decreased from 174 to 130 cfs, about 25 percent. Average concentration ratio for the two runs was 1.34.

It was concluded that although the tests with guide wall and skimming weir showed a reduction in concentration ratios, the arrangement did not produce a satisfactory reduction in the quantity of sediment entering the canal headworks. Testing was continued using bottom guide vanes.

Development of Bottom Guide Vanes at Entrance to Upstream Canal Headworks Tests 9 through 30

Tests 9 through 30 were conducted to develop a series of bottom guide vanes to be placed along the right riverbank upstream from the canal headworks, Figure 12. By controlling secondary currents, the bottom water containing a heavy sediment load can be diverted away from the canal headworks, and upper water containing a relatively light sediment load can be diverted through the canal headworks, Figure 13. Guide vanes have been studied in Russia, 1/ and have been constructed on rivers in Russia, India, and Africa.

To prepare the model for guide vane installation a slab at elevation 4661.0, Figure 12, 160 feet long and 45 feet wide, was constructed along the right riverbank. The downstream end of the slab was located 145 feet upstream from the diversion dam. The guide vanes described in the following tests were placed on this slab. In Test 9

1/"Methods of Transverse Circulation and its application to Hydrotechnics," by M. Potapov and B. Pychkine. Moscow Academy of Sciences, USSR, 1947. Translation No. 46 of Service des Etude et Recherches Hydrauliques, Paris.

the bottom vanes produced a considerable reduction in sediment intake into the canal headworks. Test results indicated that some arrangement of bottom vanes could probably be developed which would result in satisfactory performance. However, considering the many variables inherent in a set of vanes, a hit and miss type of testing program might require prohibitive amounts of testing to develop the optimum arrangement. An orderly plan was therefore developed which, it was believed, would eliminate repetitious tests. The variables were evaluated in the following order:

1. Determine satisfactory vane spacing.

2. Determine satisfactory vane angle.

3. Determine satisfactory position of vanes with respect to canal headworks.

4. Determine satisfactory vane length.

5. Determine satisfactory vane elevation.

6. Determine effect of number of vanes.

7. Determine effect of vane cross section.

Vane Spacing--Tests 9, 10, 11, and 13

These tests were used to determine a satisfactory vane spacing for the standard test discharge. A graphical method of correlation analysis presented by Ezekiel and Fox[2] was used in analyzing results. In this method, a number of variables such as concentration ratio, concentration of total sediment moving in the river, concentration of sediment moving near the headworks, and a vane characteristic are considered in evaluating a particular arrangement. The concentration ratios are first plotted as a function of the variable of immediate interest (for example, vane spacing), then deviations of individual points from the average curve are plotted as a function of the next most important variable. Following this procedure, the influence of the variable of interest can be obtained. As a limited number of points were available for all analyses (usually 3 or 4), the conclusions drawn were necessarily limited.

Vane layouts for Tests 9, 10, 11, and 13 are shown in Figure 12. In all these tests the vanes were 50 feet long, and had a top elevation of 4665.0 feet. They were placed at an angle of 40° to the direction of

[2] "Methods of Correlation and Regression Analysis," Third Edition, Ezekiel and Fox.

flow with the tip of the downstream vane on the canal headworks centerline. In these tests the vanes were sufficiently effective that there was no significant decrease in the canal discharge. Relative effectiveness can be determined by comparing the concentration ratios summarized in Table 2.

Table 2

Test No.	No. hours test was conducted	Vane spacing ft.	Concentration of sediment entering canal headworks, ppm	Concentration of sediment in the river, ppm	Concentration ratio C_c/C_{rus}
9	26.2	16.7	41	233	0.176
10	51.2	12.0	15	161	0.093
11	31.2	26.0	34	349	0.097
13	31.2	20.0	44	262	0.168

By the multiple correlation method, the spacing of 26 feet on centers was indicated to be the most satisfactory. However, each test with vanes installed resulted in considerable improvement over previous tests.

No Vanes--Test 12

To establish a true comparison datum for the effect of the vane variables, the concentration ratio of the model with only the slab in place (the vanes were removed) was determined in a 7-hour test using the standard discharges. The concentration ratio without the vanes was 4.16; during the 7-hour test the canal discharge decreased 43 percent. It was concluded that the vanes had a considerable effect in reducing sediment intake into the canal headworks.

Vane Angle--Tests 11, 14, and 16

These tests were utilized to determine a satisfactory angle between the vanes and the direction of flow. The standard test discharges were set, and the multiple correlation method was used in analyzing results. For all three tests, the vane length was 50 feet, the vane spacing was 26 feet on centers, the tip of the downstream vane on the canal centerline, and vane top elevation was 4665.0 feet, Figure 12. No noticeable discharge decrease occurred in the canal for these tests. Results are shown in Table 3.

Table 3

Test No.	No. hours test was conducted	Vane angle to river flow	Concentration of sediment entering canal headworks, ppm	Concentration of sediment in the river, ppm	Concentration ratio C_c/C_{rus}
11	31.2	40°	34	349	0.097
14	29	35°	65	367	0.177
16	51.4	45°	33	310	0.106

It was concluded that the concentration ratio was not very sensitive to the angle at which the vanes were placed. However, from a multiple correlation analysis of the results, the 45° angle was considered to be most satisfactory.

Vane Position--Tests 15, 16, and 17

These tests were utilized to determine a satisfactory placement of the set of vanes with respect to the canal headworks. The standard test discharges of 8,760 cfs in the river and 174 cfs in the canal were used, and the multiple correlation method was used in analyzing results. For all tests, the vane length was 50 feet, vane spacing 26 feet, vane elevation 4665.0 feet, and the angle of the vane with the direction of flow was 45°, Figure 12. No noticeable decrease in canal discharge resulted during these tests which are summarized in Table 4.

Table 4

Test No.	No. hours test was conducted	Tip location of downstream vane*	Concentration of sediment entering canal headworks, ppm	Concentration of sediment in the river, ppm	Concentration ratio C_c/C_{rus}
15	26.8	5'7" upstream from canal ℄	22	467	0.047
16	51.4	On canal ℄	33	310	0.106
17	27.9	7' 11" downstream from canal ℄	28	380	0.074

*See Figure 12.

Visual observations indicated that placing the vanes either farther upstream or downstream from the canal headworks would reduce the efficiency of the vanes. The multiple correlation analysis of the three tests indicated that placing the vanes 5 feet 7 inches upstream from the canal centerline was the most satisfactory arrangement.

Vane Length--Tests 15, 18, and 19

These tests were used to determine a satisfactory vane length. The standard test discharge was set and the following conditions were constant for the three tests. Vane spacing was 26 feet on centers, vane top elevation was 4665.0 feet, angle of vane with direction of flow was 45°, and the tip of the downstream vane was placed 5 feet 7 inches upstream from the centerline of the canal headworks. Table 5 summarizes results of these tests.

Table 5

Test No.	No. hours test was conducted	Vane length ft.	Concentration of sediment entering canal headworks, ppm	Concentration of sediment in the river, ppm	Concentration ratio C_c/C_{rus}
15	26.8	50	22	467	0.047
18	30.6	40	16	303	0.053
19	29.8	30	34	333	0.102

No noticeable decrease in canal discharge occurred during the tests. Analysis of the data indicated the 50-foot vane length to be the most satisfactory.

Vane Height--Tests 15, 20, 21, 22, and 23

These tests were utilized to establish an optimum top elevation of the vanes. For this series, with the standard discharge, vane length was 50 feet, vane spacing was 26 feet on centers, angle of vane with direction of flow was 45° and the tip of the downstream vane was placed 5 feet 7 inches upstream from the centerline of the canal headworks. Four vanes were used in all tests, Figure 12. Table 6 summarizes results of these tests.

Table 6

Test No.	No. hours test was conducted	Vane top elevation	Concentration of sediment entering canal headworks, ppm	Concentration of sediment in the river, ppm	Concentration ratio C_c/C_{rus}
15	26.8	4665.0	22	467	0.047
20	29.0	4663.9	90	362	0.249
21	29.5	4664.5	26	175	0.149
22	49.0	4666.2	4	319	0.013
23	23.9	4666.8	41	456	0.090

The vanes installed for Test 20 were too low and allowed considerable sediment to pass over them producing an average decrease in canal discharge of approximately 5 percent. No significant decrease in discharge occurred during the other tests of this series.

Analyses of these data indicated the most satisfactory elevation to be between 4665.9 and 4666.2 feet. The elevation selected as most satisfactory was 4666.1, after these tests and other considerations were analyzed.

Vane Number--Test 24

To establish whether fewer than four vanes would result in sufficiently strong secondary currents to reduce sediment intake into the canal, three vanes were tested, in a manner similar to that for four vanes. The 50-foot-long vanes were placed with the tip of the downstream vane 5 feet 7 inches upstream from the canal headworks. The vanes were spaced 26 feet on centers and placed at an angle of 45° with the direction of flow. Vane top elevation was 4665.9 feet. The standard discharges were tested for runs of 18.5 and 7.0 hours. The canal discharge remained constant during the tests; the resulting average concentration ratio was 0.067.

From extensive visual observations and a comparison of Tests 24 and 22, it was apparent that four vanes were considerably more effective than three.

Vane Shape--Tests 25, 26, and 27

These tests were utilized to determine the effect of the vane cross sectional shape on the concentration ratio. In previous tests, a thin vane equivalent to a prototype vane approximately 1-inch thick had been used. In the prototype a thicker reinforced-concrete vane would probably be used and a series of tests were made to investigate the effects of an 8-inch thick and a variable thickness vane. In all three tests, four 50-foot-long vanes were used, spaced 26 feet on centers, placed at an angle of 45° with the direction of flow, and with the tip of the downstream vane 5 feet 7 inches upstream from the canal headworks centerline. Vane top elevation for Test 25 was 4665.9 feet and for Tests 26 and 27 was 4666.1. Figure 12 shows the cross sec-- tions of the vanes used in these tests. Standard test discharges of 8,760 cfs in the river and 174 cfs in the canal were used.

In Test 25, a sharp-edged lip on the 8-inch-thick vanes, extending 2 feet 6-13/32 inches upstream, was tested, Figure 12, Elevation A-A. Runs of 18.7, 6.2, 17.0 and 6.9 hours were conducted. The canal discharge remained constant throughout the runs. The average concentration ratio was 0.110.

Rectangular vanes 8 inches thick, Elevation B-B, Figure 12, were installed for Tests 26 and 27. Approximately halfway through Test 26, the wooden core of the vane swelled and spilt the sheet metal covering. The test was stopped and an all metal vane was installed for Test 27. No test data were obtained for Test 26.

In Test 27, runs of 16.9 and 6.7 hours were conducted using vanes 8 inches thick. A photograph, Figure 10b, shows the sediment deposits which formed in the canal during the test. The discharge in the canal remained constant during both runs, and the resulting average concentration ratio was 0.094. The simple rectangular cross sectional vane shape used in this test was found to be more satisfactory than the more complex cross sectional shape used in Test 25.

No Vanes--Check--Test 28

To recheck the action in the model with no vanes in place, all vanes were removed for Test 28. A 4.4-hour test was conducted. During the test the canal discharge decreased by 37 percent, and the resulting concentration ratio was 4.74. This was considered to be a good check on the results of Test 12 where the concentration ratio was 4.16.

Vane Effect at Low Flows--Tests 29 and 30

To establish the beneficial action of the vanes, if any, during low flows, Tests 29 and 30 were conducted. The discharge used for these tests was the average flow occurring for the months of August, September, and October, 680 cfs, as determined from historical data. Two hundred cfs was diverted to the canal, and 480 cfs was discharged through the low-flow channel headworks.

For Test 29 the vanes were removed and no other control structures were in the river channel. One 54-hour run was conducted.

Canal discharge decreased by 3 percent due to sediment deposits, and the resulting concentration ratio was 2.40. A photograph showing the condition of the canal after Test 29 is shown in Figure 14a.

For Test 30 the vanes used in Test 27 were replaced in the model and one run of 56 hours was conducted. No decrease in canal discharge occurred, and the resulting concentration ratio was 0.42. A photograph showing the sediment deposits in the canal, following Test 30, is shown in Figure 14b.

It was concluded that although the vanes are not as effective at low flows as at flood flows, they have real value at less than design conditions.

Summary of Tests on Bottom Guide Vanes

From the tests with bottom guide vanes it was concluded that a satisfactory method of reducing heavy sediment deposits in the Socorro Main Canal would be to maintain the canal headworks in its upstream location and place four 50-foot-long bottom guide vanes upstream from the canal headworks. The vanes should be installed along the right bank of the river at an angle of 45° to the direction of flow, with vane spacing 26 feet on centers. The downstream tip of the downstream vane should be located 5 feet 7 inches upstream from the canal headworks centerline, with vane top at elevation 4666.1 feet. This arrangement reduced the concentration ratio for the test discharge from the 2.65 of the comparison test to less than 0.1. The vanes are also effective at low discharges reducing the concentration ratio from 2.40 to 0.42 for a total river discharge of 680 cfs.

Development of Siphon Headworks Structure
Tests 31 through 37

The model was revised to simulate conditions which would result if the Socorro Main Canal headworks were moved to take advantage of the three existing headworks gates and conduits in the sluiceway, Figures 15 and 16. The skimming weir, which had been in the sluiceway of the prototype structure prior to construction of the low-flow channel headworks, was constructed in the model, as was a three-tube inverted siphon to carry water from the sluiceway beneath the low-flow channel to Socorro Main Canal. This model then essentially respresented the arrangement of the prototype canal headworks before the low-flow channel was constructed. Since the prototype headworks had operated for several trouble-free years with this general arrangement, it was believed that similar trouble-free operation would result.

A blowoff gate was constructed on the model siphon invert so that sediment deposits in the siphon could be flushed from the siphon into the low-flow channel. The low-flow channel of the prototype had been designed to transport sediment loads caused by flushing.

Standard Discharge--Test 31

The standard discharge was set and all three conduit gates were opened equally. Two runs were made, the first for 4.8 hours, and the second for 2.5 hours. The average concentration ratio for these tests was 1.06, indicating approximately equal concentrations of bed sediments in the canal and river water. This test also indicated that for the concentrations being tested, an overnight run of 12 hours on the prototype would result in approximately 1,400 cubic feet of sediment being deposited in one tube of the conduit. It was concluded that this amount of sediment should be used when blowoff tests were conducted.

Siphon Blowoff--Test 32

To determine the effectiveness of the blowoff, Test 32 was conducted. In this test the length of time required to clear one tube of 1,400 cubic feet of sediment was determined for various head differentials. The sediment was placed in the conduit, and the desired water surface elevation was set and maintained in the low-flow channel. Gates on the two siphon tubes not being tested were closed, as was the exit gate on the siphon tube being tested. The headgate of the tube containing the sediment and the blowoff gate, Figure 15, were fully opened. The length of time necessary to clear the tube of sediment was then determined with a stopwatch. A graph plotted from the data converted to prototype values is shown in Figure 17. The curve indicates that for a head differential of 8.5 feet, between the dam forebay and the water surface in the low-flow channel, approximately 45 minutes (prototype time) is required to clean a siphon tube of 1,400 cubic feet of sediment. As the head differential became smaller, the time necessary to clean the tube became greater and increased rapidly after the head differential became less than about 5 feet.

Intermittent Sluicing--Test 33

This test was conducted to determine the effect of intermittent sluicing for test discharges of 8,760 cfs in the river and 174 cfs in the canal. The sluice area was closely observed during the test and when sediment had accumulated to approximately the elevation of the invert of the conduits, the canal headgates were closed and the sluice gates were opened. When additional sluicing appeared to have no further effect in reducing the quantity of sediment in the sluiceway, the sluice gates were closed and the headgates were opened. With this method of intermittent sluicing, the concentration ratio was reduced from 1.06 in Test 31 to 0.25.

Low-flow Zero Downstream River Flow--Test 34

A low-flow test was conducted with 680 cfs in the river; 480 cfs being diverted to the low-flow channel, and 200 cfs being diverted to the canal. Runs of 5 and 5.8 hours were made. Most of the sediment passing downriver entered the low-flow channel, leaving the water diverted to the canal relatively free of sediment. The concentration ratio for these tests was 0.26.

Low-flow Sluicing--Test 35

To determine the effect of sluicing operations for low flows, a series of tests were conducted where the discharge through the sluiceway was varied between 150 and 600 cfs and the amount of sediment removed from the sluiceway area was measured. Sediment was placed in the sluiceway area to the height of the skimming weir and carefully surveyed by means of a movable point gage operating on a movable beam. Headwater and tailwater elevations were held constant. The canal gates were closed, the sluice gates were opened to provide the desired discharge, and the model was operated for 45 minutes (prototype time), keeping the headwater and tailwater elevation constant. After the test, the sluiceway area was again surveyed using the point gage, and the difference between these elevations and the elevations obtained previous to the test was used to determine the volume of sediment removed during the test.

A check on the amount of sediment removed was obtained by taking a sample of the sediment laden water discharging from the sluiceway during the middle portion of the test. These samples checked the volumetric determinations closely, resulting in differences in quantity of sediment moved of less than ± 5 percent. The eight test runs indicated, Figure 18, that the volume of sediment removed increases with discharge and rapidly becomes greater as the discharge in the sluiceway increases above approximately 450 cfs.

The results of these tests were used to determine the cost of removing sediment from the sluiceway area by the sluicing methods described. Using the cost of water given by the project as $34.90 per acre-foot, the cost of removing sediment was calculated and is shown in the curve of Figure 19. No recovery of water was assumed downstream from the dam. As shown by the curve, the cost of removing sediment becomes less as the discharge increases but remains relatively high (near $10.00 per cubic yard for a discharge of 600 cfs in the sluiceway). The costs shown are probably high as some of the sluicing water may be salvaged.

<u>Low-flow Zero-flow in Low-flow Channel--Test 36</u>

To establish the concentration ratio for the average flow occurring during the months of August, September and October, discharge in the river was set at 680 cfs, with 200 cfs being diverted to the canal and 480 cfs continuing down the river. One test of 22.5 hours was conducted. The resulting concentration ratio was 1.50.

<u>Maximum Flow in Low-flow Channel--Test 37</u>

To determine the concentration ratio when the low-flow channel was flowing near capacity and no water was being discharged through the dam, the river discharge was set at 1,700 cfs and 200 cfs was diverted to Socorro Main Canal. Runs of 6.5 and 5.2 hours were made; the resulting average concentration ratio was 1.12.

<u>Summary of Tests On Siphon Headworks Structure</u>

It was concluded that moving the canal headworks to the downstream location and constructing a siphon beneath the low-flow channel would result in a satisfactory method of reducing the sediment intake into Socorro Main Canal. For most effective operation a blowoff should be provided in the siphon so that deposits in the siphon can be flushed to the low-flow channel. Sluicing operations at the headworks structure should be conducted intermittently using the maximum discharge available to ensure most efficient operation. Blowoff operations were found to be more efficient during periods of low water level in the low-flow channel. By using the intermittent method of sluicing operation, the concentration ratio for the standard discharge was reduced from 1.06 to 0.25.

Development of Flume Headworks Structure
Tests 38 through 59

The model was revised by replacing the closed conduit inverted siphon with an open-channel flume structure, Figures 20 and 21. The three conduits under the railway, with headworks in the sluiceway, were modified in the model to discharge through a transition into a 26-foot-wide open flume with bottom elevation 2.8 feet above the invert of the conduits. The flume crossed the low-flow channel and discharged into Socorro Main Canal. A sluicing arrangement was provided in the transition region to sluice excess sediment, depositing in the transition, into the low-flow channel. This plan resulted in a headworks intake arrangement similar to that used for the siphon headworks tests. Tests 38 through 59 were conducted on this structure.

Standard Discharge--Test 38

The standard discharge of 8,760 cfs in the river was set and 174 cfs was diverted to the canal. All three conduit headgates were opened equally, and four runs of 3.8, 16.5, 5.0, and 19.0 hours were conducted. The average resulting concentration ratio for these tests was 2.53, somewhat higher than had been expected. However, on the basis of the results obtained by intermittent sluicing with the siphon in place it was believed that the concentration ratio could be reduced considerably by intermittent sluicing, since the same general arrangement of headworks had been used in the siphon tests.

Intermediate Discharge--Test 39

To determine the concentration ratio for an intermediate flow, a discharge of 1,700 cfs was set in the river; 1,500 cfs was diverted to the low-flow channel and 200 cfs was diverted to Socorro Main Canal. Runs of 19.8, 4.8, and 5.8 hours were made. The average resulting concentration ratio, 0.405, was considered satisfactory.

Low Discharge--Test 40

To check the average summer flow condition, a discharge of 680 cfs was set in the river; 200 cfs was diverted to the canal and 480 cfs was diverted to the low-flow channel. Runs of 27.3 and 24.5 hours were made. The average resulting concentration ratio was 0.26. Of interest is the fact that the concentration ratio for this test is the same as that measured for Test 34. Similar conditions in the river channel and at the canal headworks occurred in both tests.

Skimming Lip--Tests 41, 42, and 43

These tests were conducted to determine the advantage, if any, of a skimming lip in the canal sluicing area upstream from the open flume,

Figure 22. A river discharge of 8,760 cfs was set and 265 cfs was passed through the canal headgates. The low-flow channel sluice gate was opened to allow 65 cfs to be discharged, leaving 200 cfs to continue down the canal.

The results of these three tests were compared using the ratio of concentration of sediment in the water being sluiced from the canal (C_{cs}) to the concentration of sediment in the water continuing down the canal (C_c). A summary of the results is given in Table 7.

In Test 41, a vertical wall curved in plan was used to connect the conduit invert to the flume invert, Figure 22. One 7-hour test was conducted. Results indicated the concentration ratio C_{cs}/C_c to be 2.02, meaning that the concentration of sediment in the water being sluiced from the canal was approximately twice as high as the concentration of sediment in the canal water.

In Test 42, a blunt-nosed skimming lip was added as a horizontal extension to the curved wall, Figure 22. One test of 7.2 hours was conducted. The resulting concentration C_{cs}/C_c, was 1.01, indicating a decrease in efficiency from Test 41.

In Test 43, a sharp-nosed skimming lip, Figure 22, was installed along the curved wall, and two runs of 4.5 hours each were conducted. The concentration ratio C_{cs}/C_c was 3.02. Although this indicated an improvement over Test 41, the lip was not recommended for prototype use because it would be difficult to construct.

Table 7

Test No.	Discharge through canal headworks cfs	Discharge down canal cfs	Sediment concentration entering headworks ppm	Discharge from canal sluice gate cfs	Sediment concentration in water sluiced from canal ppm	C_{cs}/C_c
41	265	200	1,472	65	2,969	2.02
42	265	200	1,041	65	1,053	1.01
43	265	200	904	65	2,732	3.02

Floating Vanes--Test 44 and 45

Tests on the bottom guide vanes, discussed in Tests 9 through 30, indicated that they were capable of controlling heavy bottom loads. It was therefore decided to investigate the effects of surface vanes in this installation. For preliminary investigations, a discharge of 8,760 cfs was set in the river and 265 cfs was diverted through the canal headworks.

A raft of 24 floating vanes each 2 feet 3-1/2 inches deep and 7 feet 6 inches long (prototype dimensions) was anchored in the sluiceway near the canal headgates, Figure 23. The vanes were set 20° from the direction of flow in a manner to divert topwater to the headworks structure. In Test 44, the skimming weir in the river sluiceway was left in place. Average sediment concentration in the canal water during a 20.8-hour test was 200 ppm by weight. The skimming weir was removed for Test 45, and the average sediment concentration in the canal water during a 20.6-hour test was 496 ppm. Sediment concentrations in the river were not obtained. It was concluded that the vanes did not improve sediment conditions.

Unsymmetrical Flow--With Vanes--Test 46

To investigate the effect of an unsymmetrical discharge through the sluiceway with the vanes in place, a discharge of 8,760 cfs was set in the river, and 265 cfs was diverted through the canal headworks. The raft was left in the same location and at the same angle as for Test 45. The sluice gate nearest the canal headworks was closed, and the other sluice gate was opened. In other tests the discharge had been equally divided between both gates. One 22-hour run was conducted, and the resulting average concentrat[illegible] was 0.33, a considerable improvement over previous te[illegible] arrangement with the same discharges.

Unsymmetrical Flow--No Vanes--Test 47

To determine the concentration ratio for the unsymmetrical flow without the vanes in place, the vane raft was removed, and discharges and gates were set as in Test 46. One run of 22.2 hours was conducted. The resulting concentration ratio was 1.96. It was concluded that the vane raft had reduced the concentration ratio from 1.96 to 0.33.

Vane and Raft Placement--Test 48

To aid in determining the effect of raft placement and vane angle, the vane raft was moved upstream in the sluiceway as shown in Figure 23, and the vanes were set at an angle of 30° to the direction of flow. A discharge of 8,760 cfs was set in the river, and 200 cfs was diverted to the canal. Both sluice gates and all river gates were opened equally. A 25.1-hour test was conducted. The resulting concentration ratio was 0.83.

Small Vane Raft--Test 49

A twelve vane raft, Figure 23, was designed and installed in the sluiceway area. The vanes were 7 feet 6 inches long, 2 feet 3-1/2 inches deep and were placed at 30° to the direction of flow. A discharge of 8,760 cfs was set in the river and 200 cfs was diverted to the canal. A 26.2-hour test was conducted, with a resulting concentration ratio of 1.57. This indicated some improvement over the concentration ratio 2.53 of Test 38.

Small Vane Raft Placement--Test 50

The small vane raft was moved downstream so that the vanes were in front of the canal headworks. Discharges were set as in Test 49, and a 19.5-hour test was conducted. The resulting concentration ratio was 1.41. The smaller vane raft appeared to have less effect on bottom loads than the large vane raft, and its placement appeared to be less critical.

Bottom Vanes--Test 51

To check the efficiency of bottom guide vanes as compared to surface guide vanes, a set of three bottom guide vanes was installed at a 45° angle to the flow just upstream from the canal headworks, Figure 23. The vanes were spaced on 18-foot centers, their top elevation was at 4666.16, and they extended halfway across the sluiceway. A discharge of 8,760 cfs was set in the river, and 174 cfs was diverted to the canal. A 35.4-hour test was conducted, and the resulting concentration ratio was 1.28. There was no improvement with the bottom vanes in place and it was concluded that the vanes were of little benefit in the confined area of the sluiceway.

Bottom Vanes--Unsymmetrical Discharge--Test 52

Test conditions were identical to those for Test 51, with the exception of the sluice gate settings. For Test 52, the sluice gate nearest the headworks was closed and the other sluice gate opened enough to pass the total sluicing discharge. A 22.7-hour test was conducted which resulted in a concentration ratio of 0.57. Although the unsymmetrical flow arrangement resulted in an improved concentration ratio, the resulting value was greater than the 0.33 obtained in Test 46. It was concluded that the large surface vane raft was more effective than the bottom vanes.

Bottom Vanes--Intermediate Discharge--Test 53

The efficiency of the bottom vanes was tested for a discharge of 2,270 cfs in the river and 200 cfs diverted to the canal. All gates were opened equally and a 25.7-hour test was conducted which resulted in an average concentration ratio of 1.51. This ratio was greater than that for Test 51, and helped confirm the conclusion drawn from Test 51, that bottom guide vanes are not effective when placed in the confined area of the sluiceway. From the results of Test 53 it was also concluded that the bottom guide vanes are less effective at intermediate discharges.

Small Vane Raft--Intermediate Discharge--Tests 54 and 55

The small surface vane raft was again placed in the sluiceway, Figure 23, a discharge of 2,270 cfs was set in the river, and 200 cfs was diverted to the canal. In Test 54, all gates on the dam were opened equally. The sluice gate nearest the canal headworks was closed and the sluice gate on the opposite side of the sluiceway was opened to pass the necessary discharge. A 19.2-hour run was conducted. The resulting concentration ratio was 0.125. Test 55 was similar to Test 54, with the exception that both sluice gates were opened equally. A 4.7-hour run was conducted, with a resulting concentration ratio of 1.06. These tests again indicated that the concentration ratio could be reduced by passing all of the sluicing water through the sluice gate on the side opposite the canal headworks.

Bottom Vanes--Position--Tests 56 and 57

To determine the effect of position on sediment control, the bottom guide vanes used in Tests 51, 52, and 53 were reinstalled 4-1/2 inches downstream from their previous position, Figure 23. A discharge of 2,270 cfs was set in the river and 200 cfs was diverted to the canal. In Test 56, all river and sluice gates were opened equally and three runs totaling 40.8 hours were made. The average resulting concentration ratio was 1.15. Test 57 was similar to Test 56 with the exception of the sluice gate settings. For Test 57, the sluice gate nearest the canal headworks was closed and the other sluice gate opened to pass the entire sluice discharge. Three runs totaling 27.2 hours were conducted which resulted in a concentration ratio of 1.29. It was concluded that this vane placement was less satisfactory than the vane positions used in Tests 51, 52, and 53.

Surface and Bottom Vanes--Tests 58 and 59

These tests were conducted to determine if additional sediment could be diverted to the low-flow channel with either surface or bottom guide vanes. For each test, a flow of 1,700 cfs was set in the river; of this, 1,500 cfs was diverted to the low-flow channel and 200 cfs was diverted to the canal. For Test 58, the large surface vane raft was placed in front of the low-flow channel as shown in Figure 23. The vanes were set to divert top water away from the low-flow channel headworks, so that the relatively clear water would continue to the canal headworks. The vanes were set at 20° to the direction of flow, and a 7.2-hour test was conducted. The resulting concentration ratio was 0.093.

For Test 59, eight 25-foot bottom vanes with their top elevation at 4666.16 were placed at 45° to the direction of flow as shown on Figure 23. A 7-hour test was conducted which resulted in a concentration ratio of 0.016.

It was concluded that under certain operating conditions guide vanes would be effective in diverting additional sediment to the low-flow channel.

CONCLUSIONS AND RECOMMENDATIONS

Fifty-nine tests were conducted on a 1:20 scale hydraulic model of San Acacia Diversion Dam and Socorro Main Canal headworks. These tests and their results are summarized in Table 8. The tests indicated that three methods could be used to reduce the sediment intake into Socorro Main Canal.

The first method was to maintain the canal headworks in its upstream location and place four 50-foot-long bottom guide vanes upstream from the canal headworks. The vanes should be installed along the right bank of the river at an angle of 45° to the direction of flow, with their upstream ends near the bank. Vane spacing should be 26 feet on centers, vane top should be located at elevation 4666.1 feet, and the downstream tip of the downstream vane should be located 5 feet 7 inches upstream from the canal headworks centerline. This arrangement was most efficient for flood discharges, and reduced the concentration ratio for the test discharge from 2.65 to less than 0.1. The vanes for the recommended arrangement are shown in Figure 12, Tests 26, 27, and 30.

The second method was to move the Socorro Main Canal headworks to the downstream location in the sluiceway and construct a 3-barrel inverted siphon under the low-flow channel to convey water to Socorro Main Canal. This arrangement, shown in Figures 15 and 16, included a blowoff in the siphon from which sediment deposits could be flushed into the low-flow channel. Best performance occurred when sluicing operations were intermittent. For this type of operation the concentration ratio for the standard discharge was reduced from 1.06 to 0.25. This method was also effective when the discharge was reduced to 1,700 cfs and water was being diverted to the low-flow channel.

The third method was to move the Socorro Main Canal headworks to the downstream location in the sluiceway and construct a 26-foot-wide open channel flume across the low-flow channel. This arrangement shown in Figures 2c and 21 was recommended for use in the prototype structure and included a sluice gate upstream from the flume from which sediment deposits collecting in the area could be sluiced into the low-flow channel. The concentration ratio for the standard test discharge could be reduced from 1.06 to 0.25 similar to that for the second method by the use of intermittent sluicing. This third method is also effective for a river discharge of 1,700 cfs if the excess water is diverted to the low-flow channel.

Table 8

SUMMARY OF TEST DATA
Middle Rio Grande Project, New Mexico
San Acacia Diversion Dam
1:20 Hydraulic Model Study

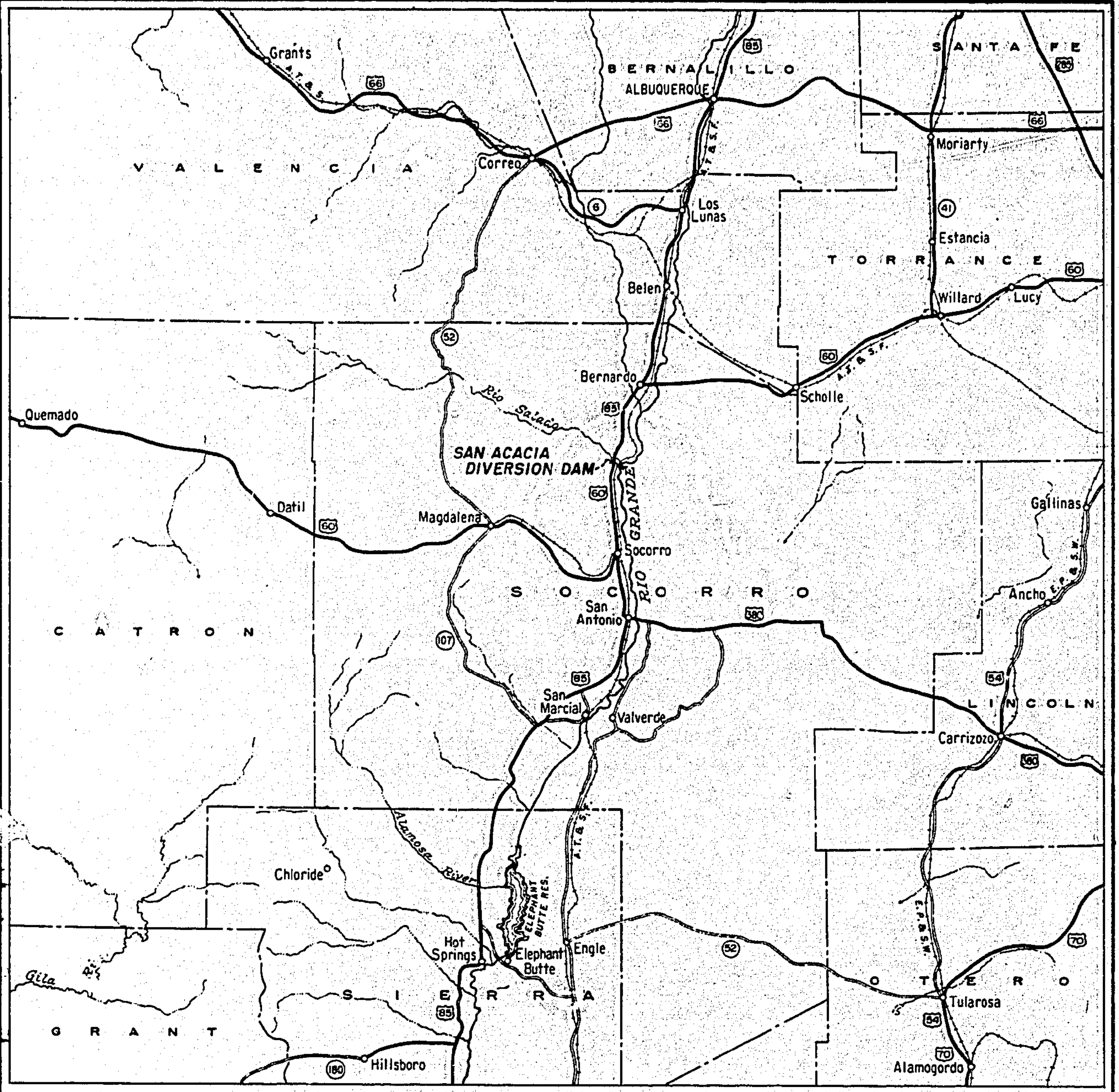
Column

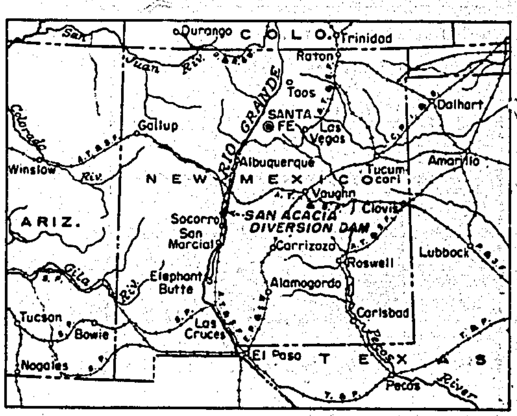
1 Test number
2 Total number of hours test was conducted (model time)
3 Average prototype discharge in the Rio Grande in cubic feet per second (cfs)
4 Average concentration of bed sediments in the river in parts per million by weight (ppm)
5 Average prototype discharge being diverted to Socorro Main Canal in cfs
6 Average concentration of bed sediments entering the canal headworks in ppm
7 Average prototype discharge being diverted to the low-flow channel in cfs
8 Average concentration of bed sediments entering the low-flow channel headworks in ppm
9 Ratio of concentration of bed sediments in the canal divided by concentration of bed sediments in the river
10 Short description

1	2	3	4	5	6	7	8	9	10
1	8.8	8,760	338	135	896	0	0	2.65	Similar to 1958 prototype
2	52.5	8,760	407	112	1,178	0	0	2.89	Island and U.S. protrusion removed
3	36.0	8,760	313	140	620	0	0	1.98	Island removed
4	28.7	8,760	364	136	1,971	0	0	5.41	Island and protrusions removed
5	50.5	8,760	467	156	1,395	0	0	2.99	Skimming weir and guide wall
6	6.5	8,760	333	169	524	0	0	1.57	Skimming weir and guide wall
7	3.5	8,760	726	174	1,019	0	0	1.40	Skimming weir and guide wall
8	29.0	8,760	360	169	484	0	0	1.34	Skimming weir and guide wall
9	26.2	8,760	233	174	41	0	0	0.176	Four bottom vanes
10	51.2	8,760	161	174	15	0	0	0.093	Four bottom vanes
11	31.2	8,760	349	174	34	0	0	0.097	Four bottom vanes
12	7.0	8,760	385	125	1,601	0	0	4.16	No control
13	31.2	8,760	262	174	44	0	0	0.168	Four bottom vanes
14	29.0	8,760	367	174	65	0	0	0.177	Four bottom vanes
15	26.8	8,760	467	174	22	0	0	0.047	Four bottom vanes
16	51.4	8,760	310	174	33	0	0	0.106	Four bottom vanes
17	27.9	8,760	380	174	28	0	0	0.074	Four bottom vanes
18	30.6	8,760	303	174	16	0	0	0.053	Four bottom vanes
19	29.8	8,760	333	174	34	0	0	0.102	Four bottom vanes
20	29.0	8,760	362	174	90	0	0	0.249	Four bottom vanes
21	29.5	8,760	175	174	26	0	0	0.149	Four bottom vanes
22	49.0	8,760	319	174	4	0	0	0.012	Four bottom vanes
23	23.9	8,760	456	174	41	0	0	0.090	Four bottom vanes
24	25.5	8,760	402	174	27	0	0	0.067	Three bottom vanes
25	48.8	8,760	337	174	37	0	0	0.110	Four bottom vanes
26		(No data obtained)				0	0		Four bottom vanes
27	23.6	8,760	362	174	34	0	0	0.094	Four bottom vanes
28	4.4	8,760	345	137	1,635	0	0	4.74	No control
29	54.0	680	129	200	310	480	56	2.40	No control
30	56.0	680	59	200	25	480	74	0.420	Four bottom vanes
31	7.3	8,760	1,340	109	1,424	0	0	1.06	Siphon
32	(Blowoff tests)								Siphon
33		8,760	1,050	159	259	0	0	0.247	Siphon
34	10.8	680	310	200	80	480	407	0.258	Siphon
35	(Sluicing tests)								Siphon
36	22.5	680	84	200	126	0	0	1.50	Siphon
37	11.7	1,700	109	200	122	1,500	107	1.12	Siphon
38	31.8	8,760	610	174	1,542	0	0	2.53	Flume
39	30.4	1,700	336	200	136	1,500	363	0.405	Flume
40	51.8	680	154	200	40	480	217	0.260	Flume
41	7.0	8,760	414	200	1,472	0	0	3.55	Flume
42	7.2	8,760	328	200	1,041	0	0	3.17	Flume
43	9.0	8,760	263	200	904	0	0	3.44	Flume
44	20.8	8,760	*	265	200	0	0	-	Flume and floating vane raft
45	20.6	8,760	*	265	496	0	0	-	Flume and floating vane raft
46	22.0	8,760	386	265	127	0	0	0.329	Flume and floating vane raft
47	22.2	8,760	397	265	779	0	0	1.96	Flume
48	25.1	8,760	280	200	232	0	0	0.829	Flume and floating vane raft
49	26.2	8,760	270	200	423	0	0	1.57	Flume and floating vane raft
50	19.5	8,760	216	200	304	0	0	1.41	Flume and floating vane raft
51	35.4	8,760	274	174	350	0	0	1.28	Flume and three bottom vanes
52	22.7	8,760	255	174	145	0	0	0.57	Flume and three bottom vanes
53	25.7	2,270	39	200	59	0	0	1.51	Flume and three bottom vanes
54	19.2	2,270	16	200	2	0	0	0.125	Flume and floating vane raft
55	4.7	2,270	106	200	112	0	0	1.06	Flume and floating vane raft
56	40.8	2,270	106	200	122	0	0	1.15	Flume and three bottom vanes
57	27.2	2,270	112	200	145	0	0	1.29	Flume and three bottom vanes
58	7.2	1,700	54	200	5	1,500	61	0.093	Flume and floating vane raft
59	7.0	1,700	304	200	5	1,500	344	0.016	Flume and bottom vanes

*Data was not obtained.

FIGURE I





INDEX MAP

EXPLANATION

- PAVED
- IMPROVED
- UNCLASSIFIED

10 0 10 20 30

SCALE OF MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MIDDLE RIO GRANDE PROJECT-NEW MEXICO

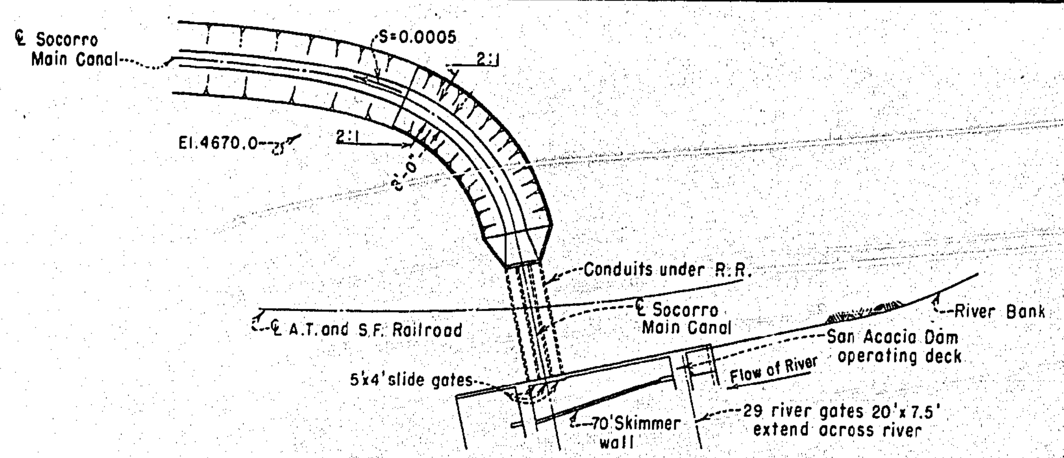
SAN ACACIA DIVERSION DAM REHABILITATION

LOCATION MAP

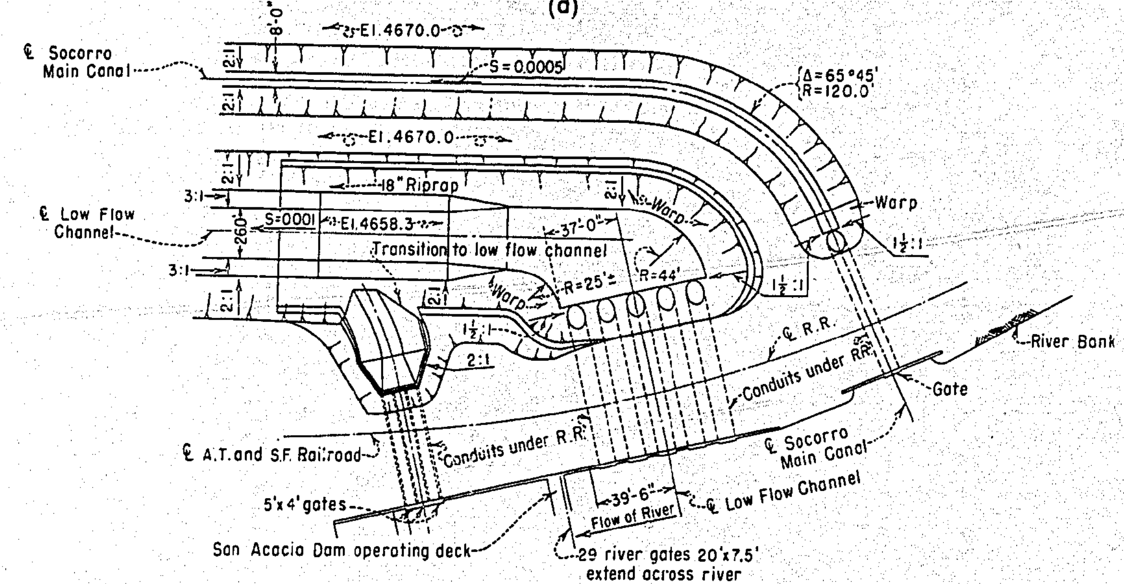
DRAWN B.F.W. SUBMITTED O. L. Rice
TRACED B.F.W. RECOMMENDED T.W. Mermel
CHECKED J.S.C. L.G.P. APPROVED Grant Bloodgood
ASSOC. CHIEF ENGINEER

DENVER, COLORADO OCT. 7, 1958

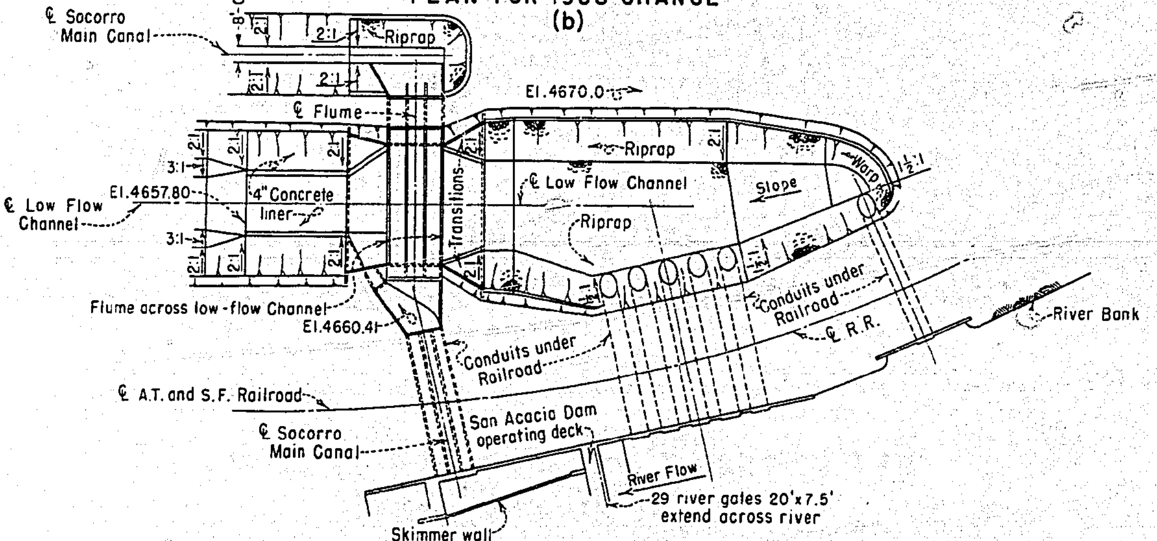
163-D-241



PLAN BEFORE 1958
(a)

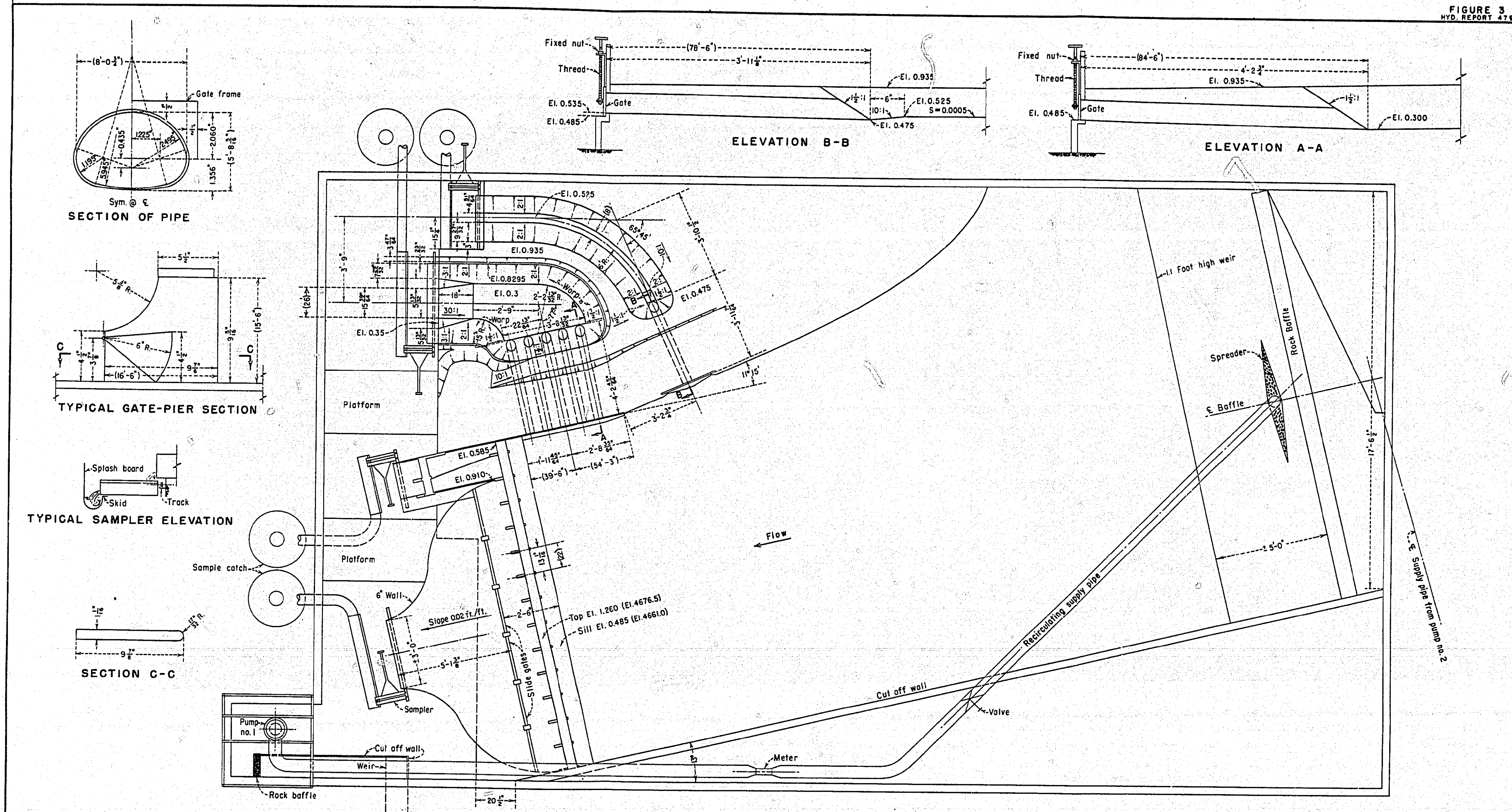


PLAN FOR 1958 CHANGE
(b)



DESIGN RECOMENDED AFTER MODEL STUDY
(c)

MIDDLE RIO GRANDE PROJECT NEW MEXICO
SAN ACACIA DIVERSION DAM
PLANS OF HEADWORKS AT DIVERSION DAM
1:20 HYDRAULIC MODEL STUDY

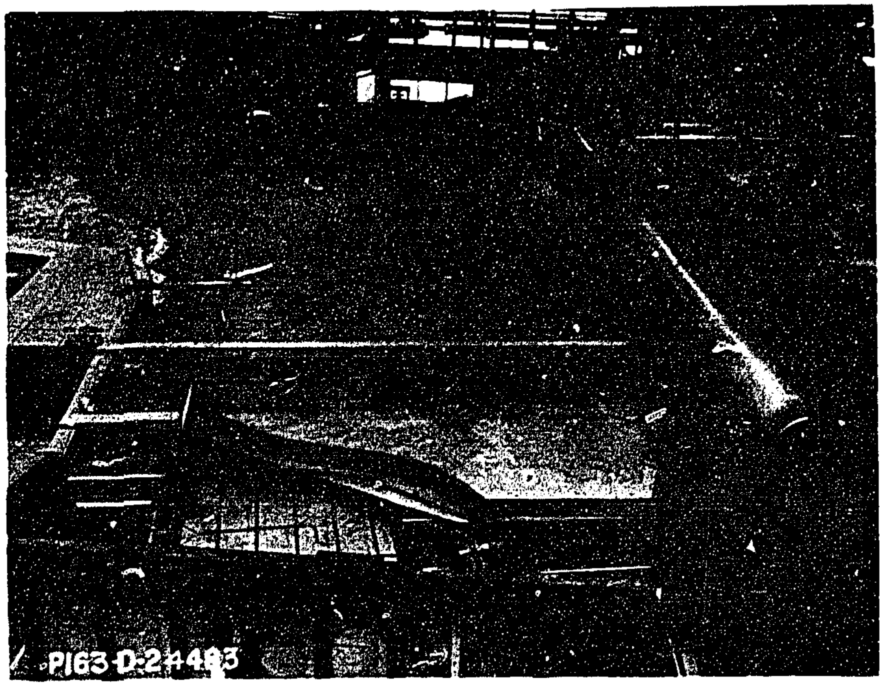


MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM

GENERAL PLAN AND SECTIONS OF MODEL

1:20 HYDRAULIC MODEL STUDY

NOTE
Prototype dimension are shown in parentheses ( ).

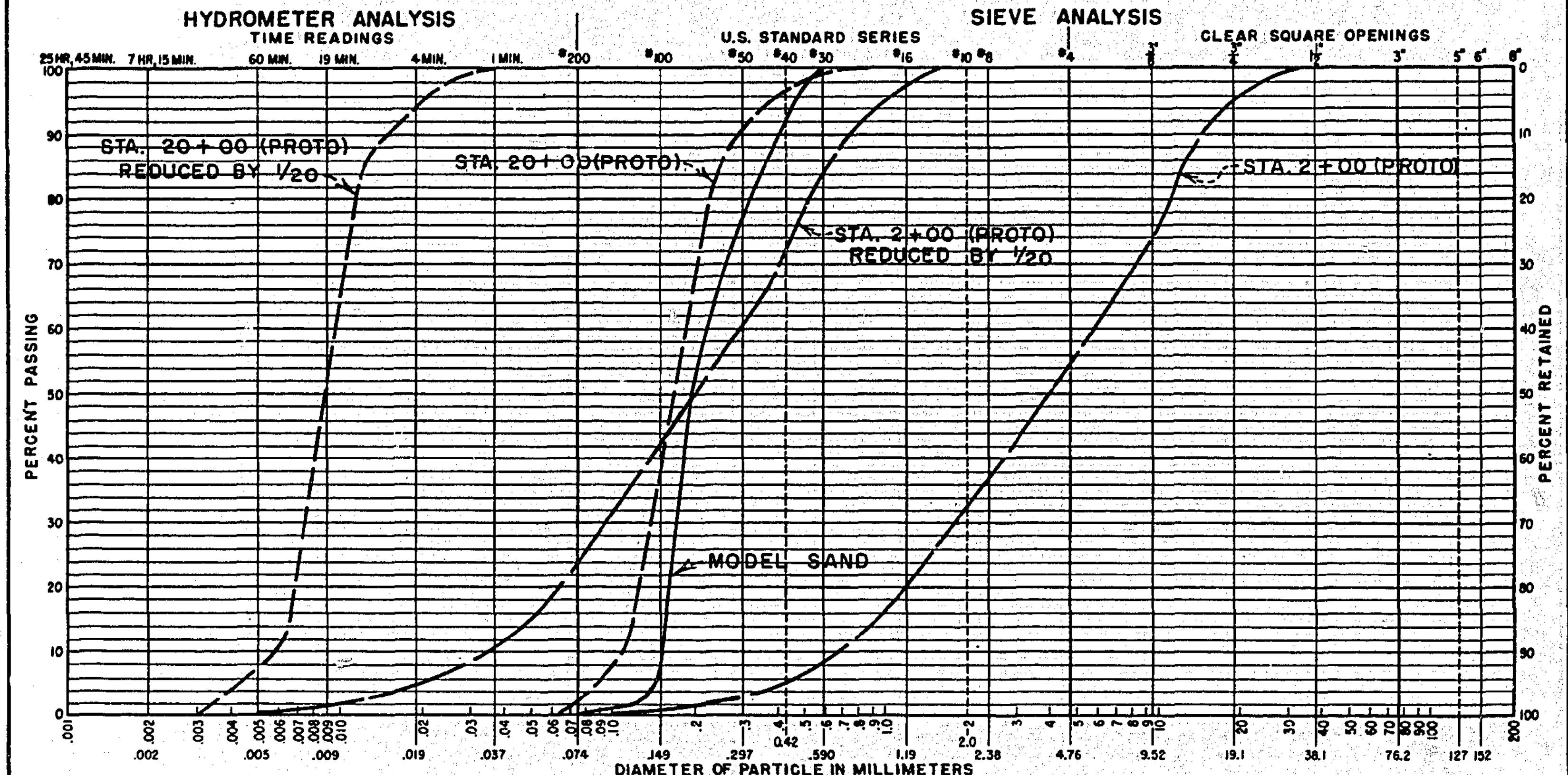


(a)
Overall View of Model

(b)
Sample ıng Obtained from River Flow

Middle Rio Grande Project, New Mexico
San Acacia Diversion Dam
THE MODEL AND SEDIMENT SAMPLING PROCEDURE

1:20 Hydraulic Model Study



NOTES: PROTOTYPE MATERIAL IS FROM SOCORRO MAIN CANAL

GRADATION TEST

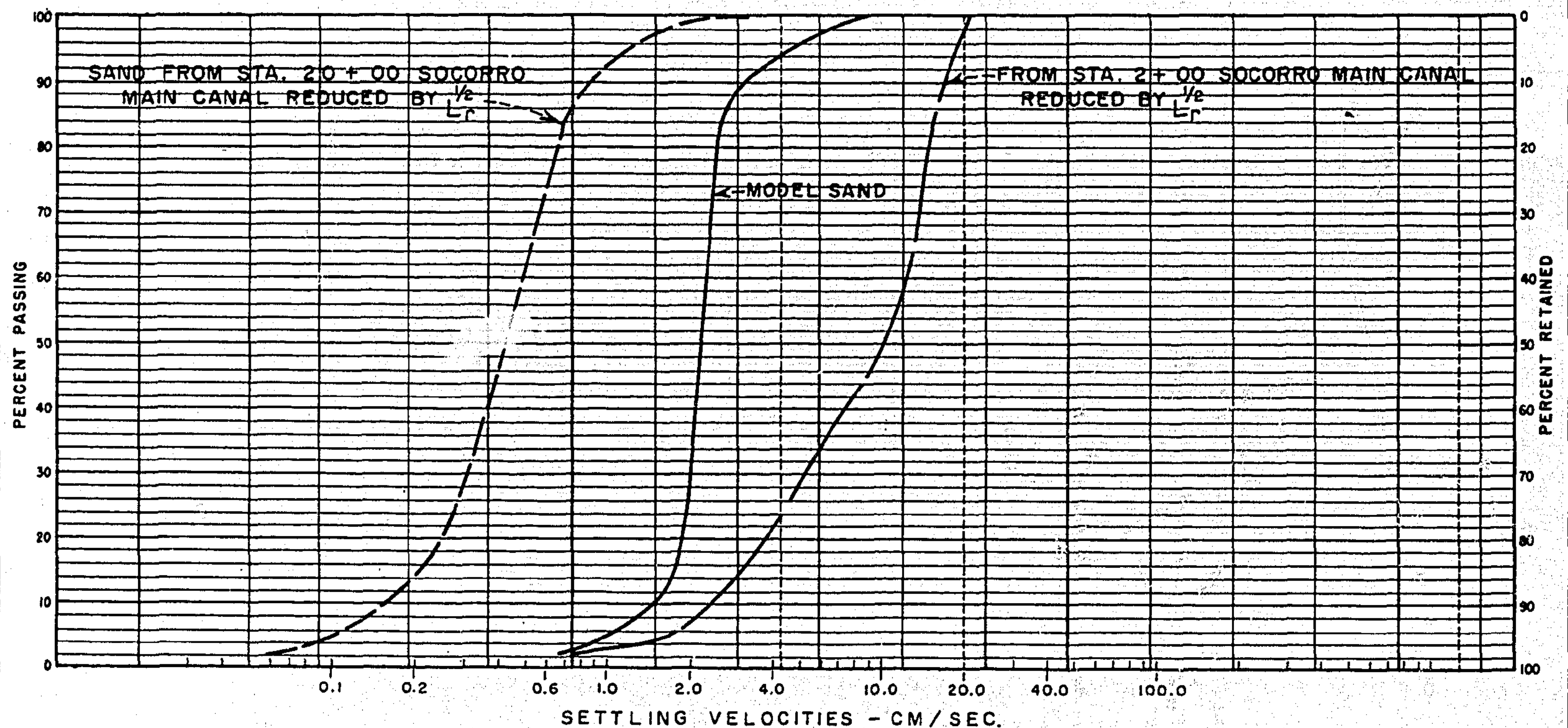
MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM

SEDIMENT GRADATION ANALYSIS CURVES MODEL AND PROTOTYPE

1:20 HYDRAULIC MODEL STUDY

LABORATORY SAMPLE No.______ FIELD DESIGNATION______ EXCAVATION No.______ DEPTH______ FT.

FIGURE 5
HYD. REPORT 479

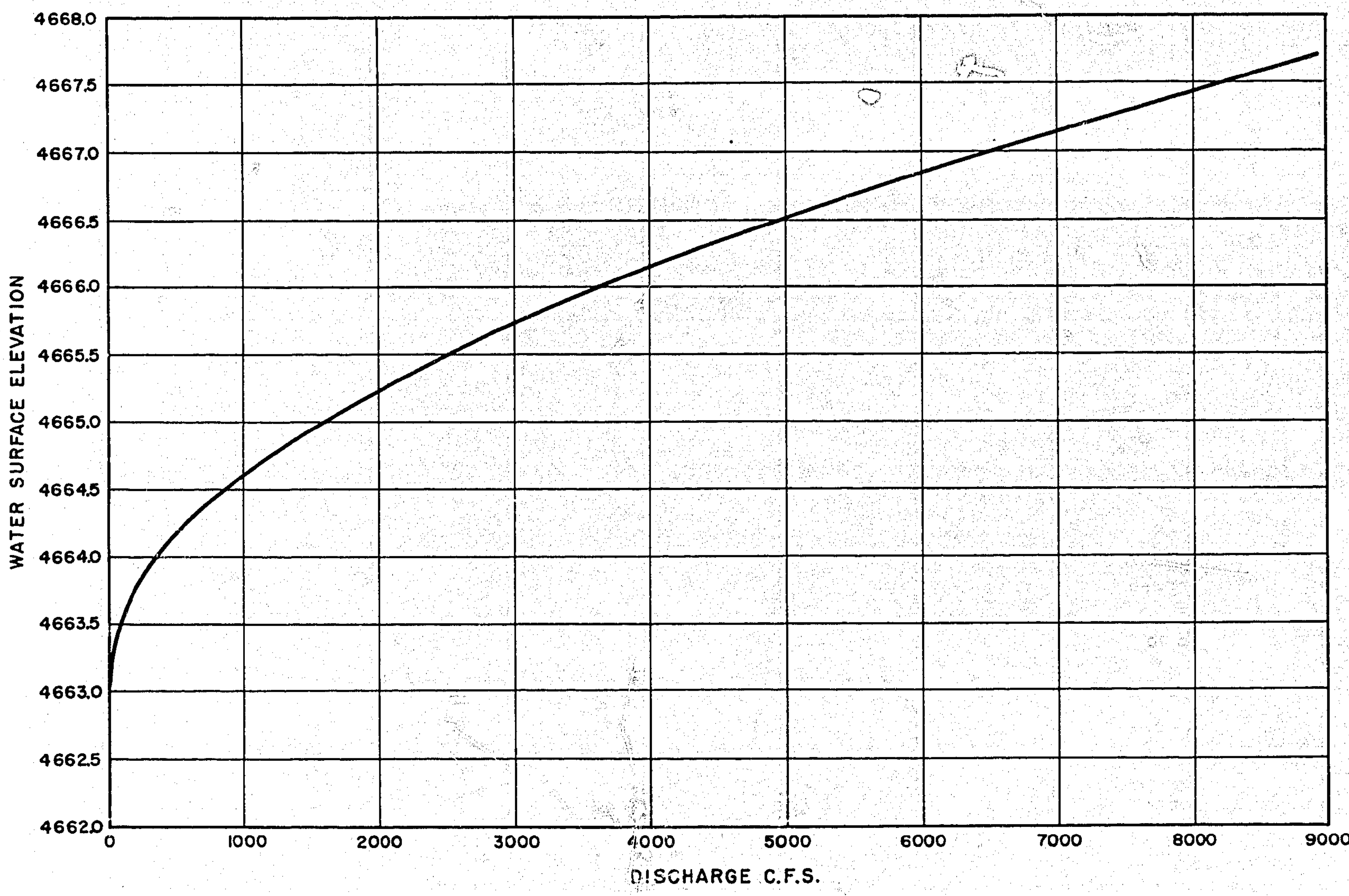


MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM

SETTLING VELOCITIES OF MODEL AND PROTYPE MATERIAL

1:20 HYDRAULIC MODEL STUDY

FIGURE 6
HYD. REPORT 479



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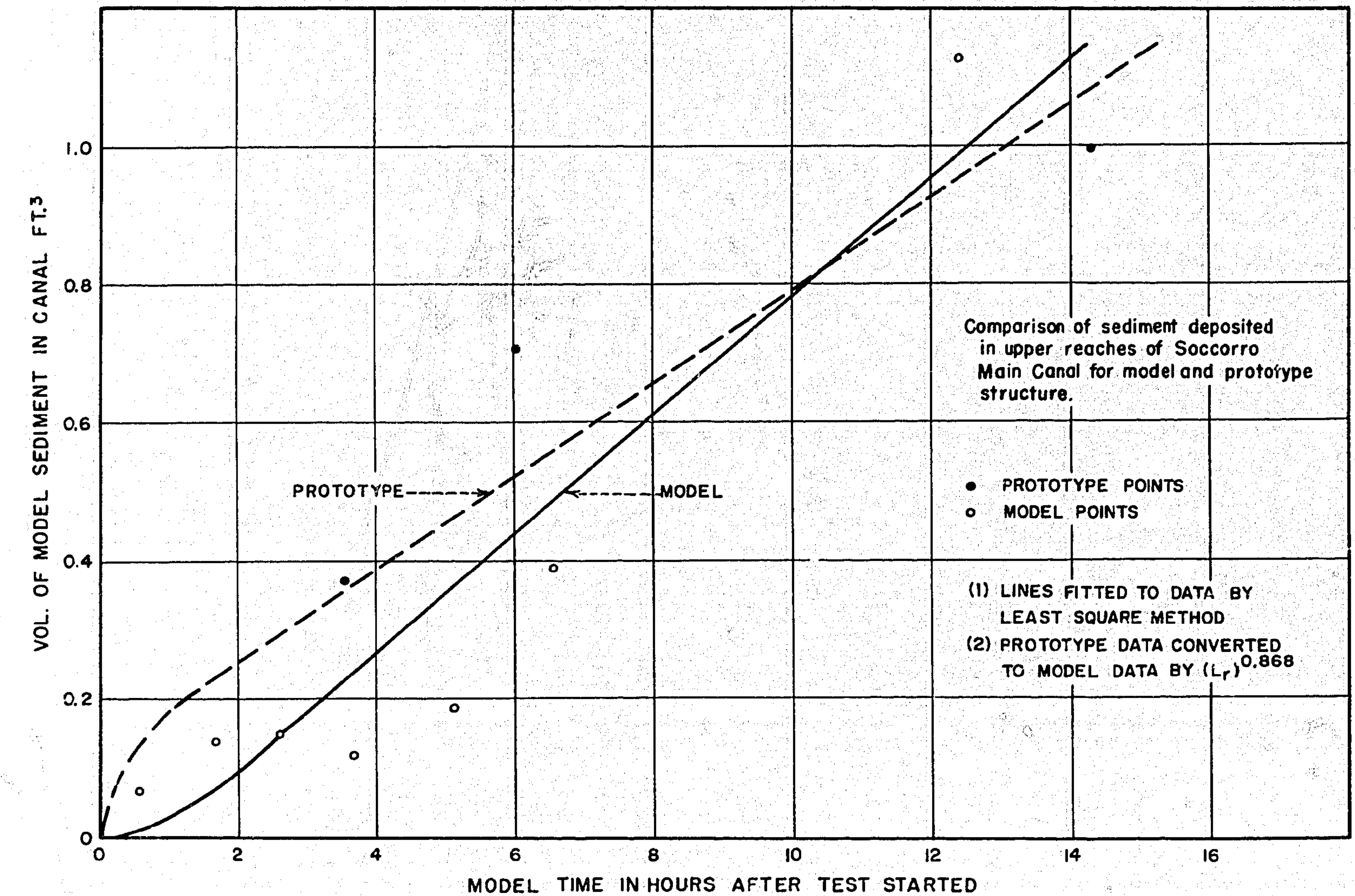
MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM
TAILWATER CONDITIONS BELOW DAM BASED ON U.S.G.S. MEASUREMENTS
1:20 HYDRAULIC MODEL STUDY

FIGURE 7
HYD. REPORT 479



MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM
COMPARISON BETWEEN MODEL AND PROTOTYPE DATA
1:20 HYDRAULIC MODEL STUDY

FIGURE 8
HYD. REPORT 479

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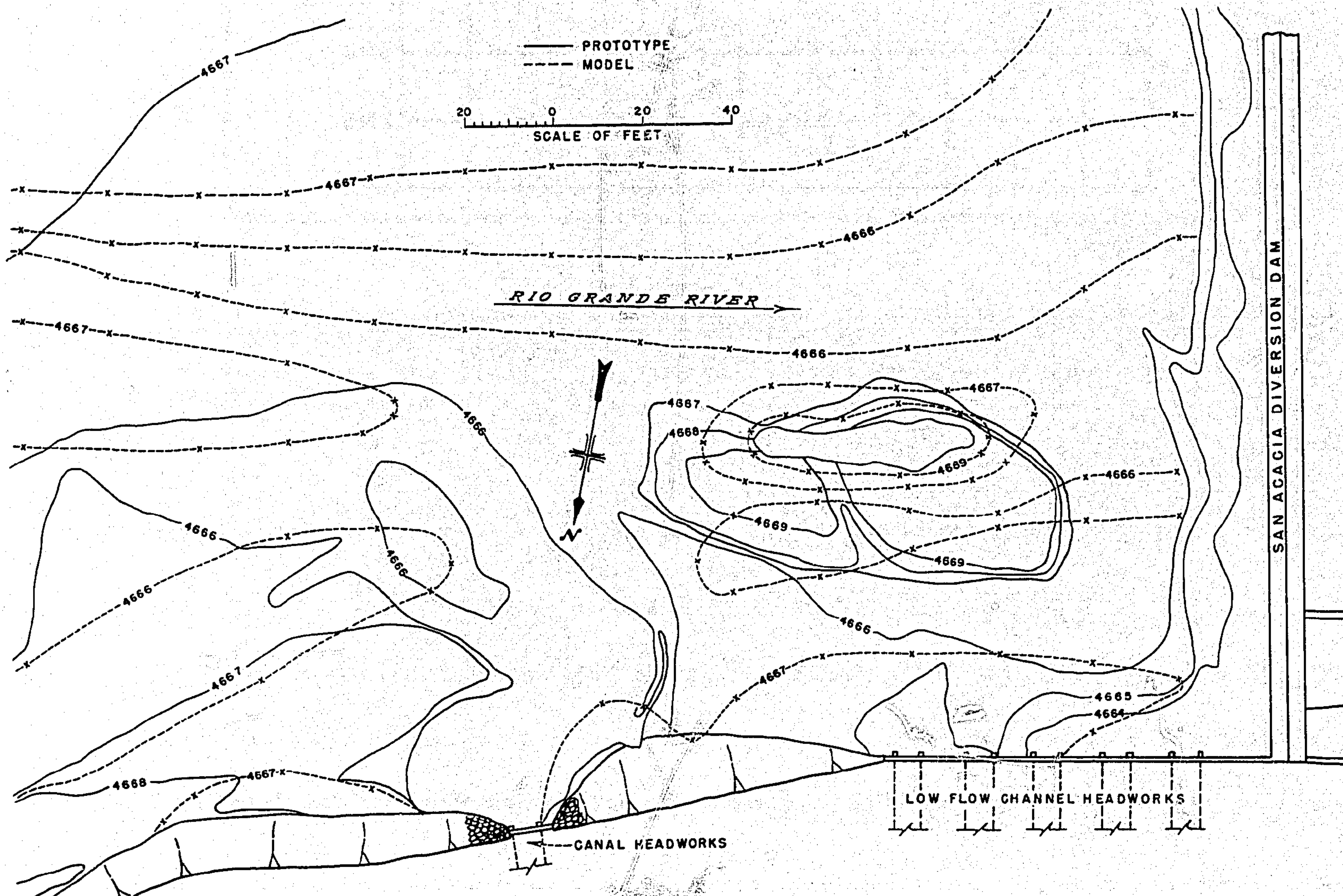
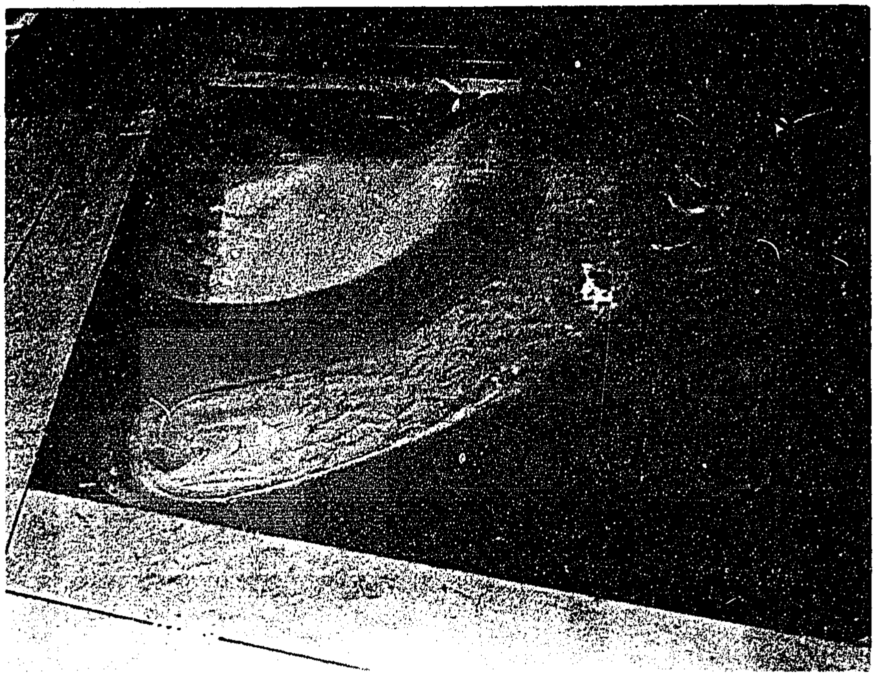
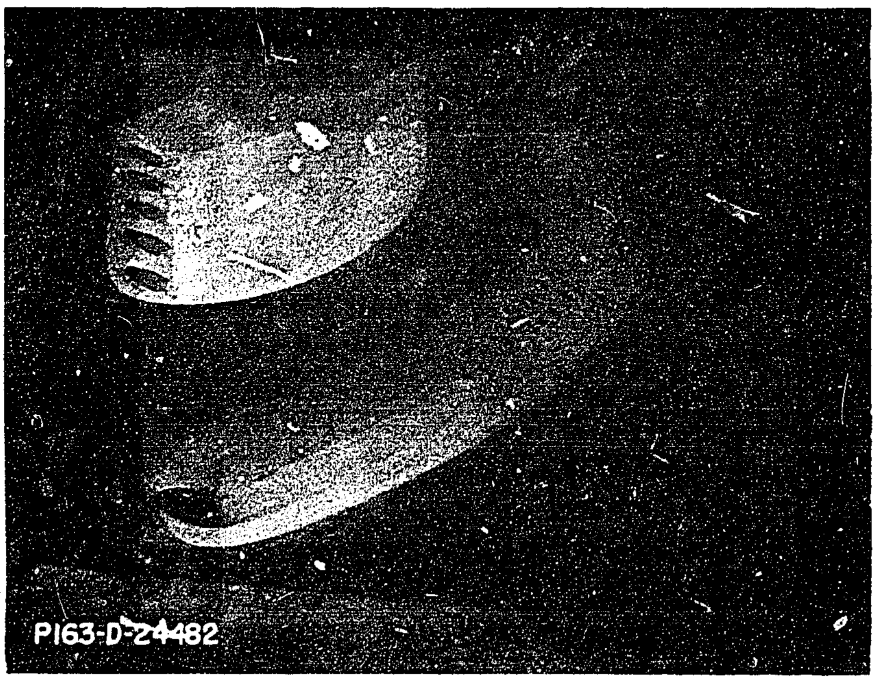


MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM
MODEL CONTOURS AFTER TEST 1
COMPARED TO PROTOTYPE CONTOURS OF 9-21-59
1:20 HYDRAULIC MODEL STUDY

FIGURE 9
HYD. REPORT 479



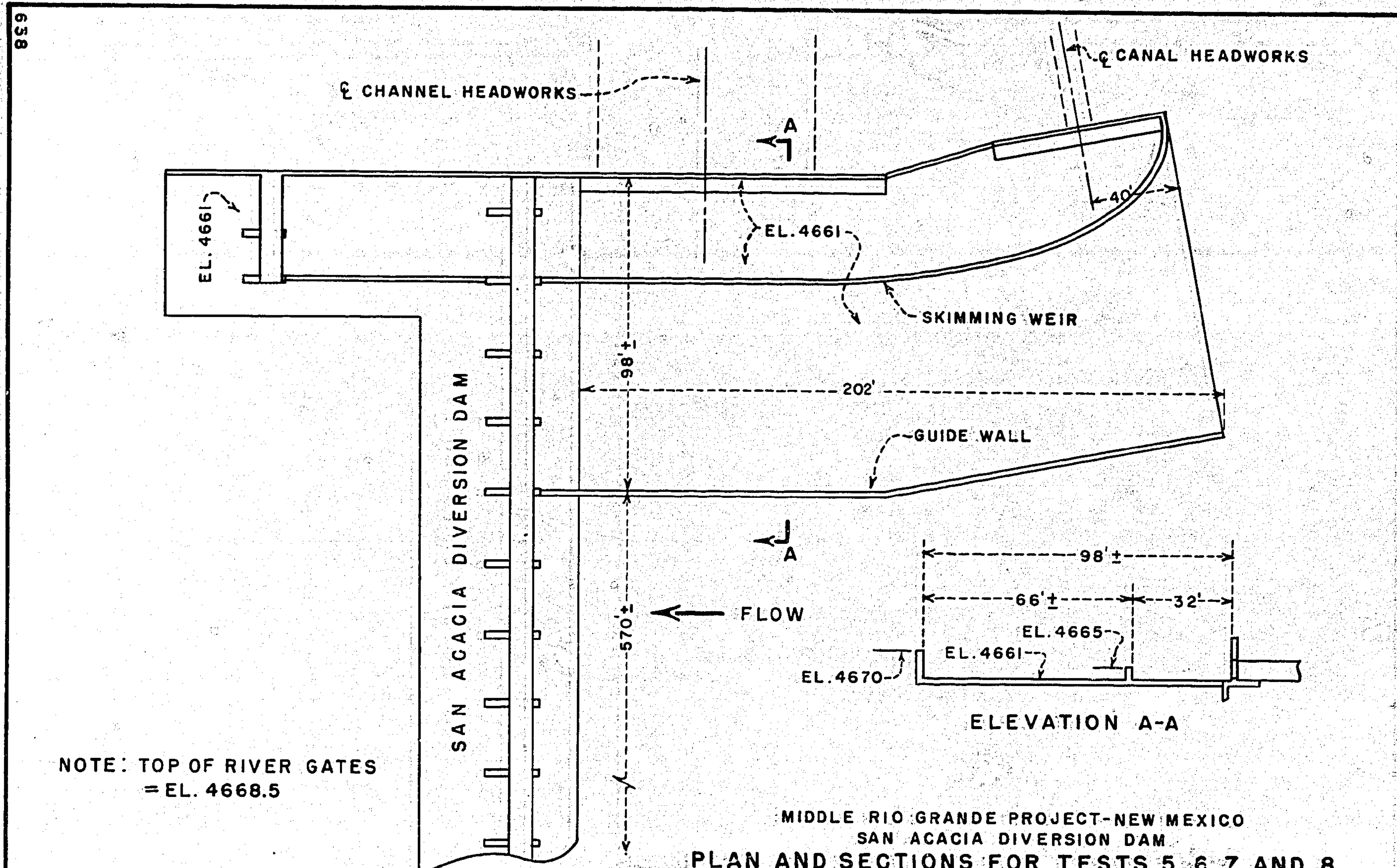
(a)
Without Bottom Guide Vanes



(b)
With Bottom Guide Vanes

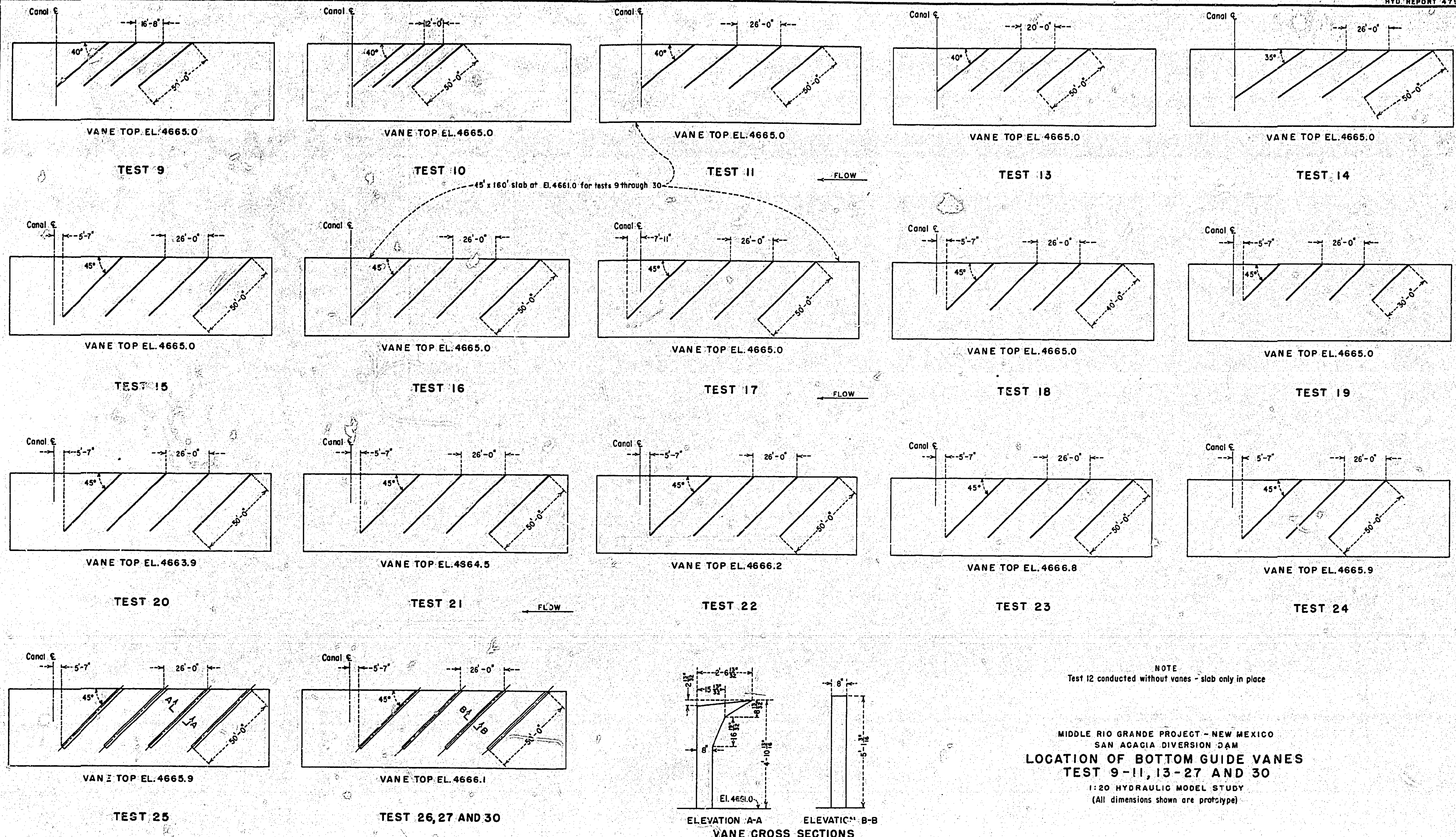
Middle Rio Grande Project, New Mexico
San Acacia Diversion Dam
MODEL SEDIMENT DEPOSITS IN SOCORRO MAIN CANAL WITHOUT AND WITH BOTTOM GUIDE VANES, 1958 PROTOTYPE CONDITIONS

1:20 Hydraulic Model Study



MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM
PLAN AND SECTIONS FOR TESTS 5, 6, 7 AND 8
1:20 HYDRAULIC MODEL STUDY
All dimensions shown are prototype.

FIGURE 11
HYD. REPORT 479

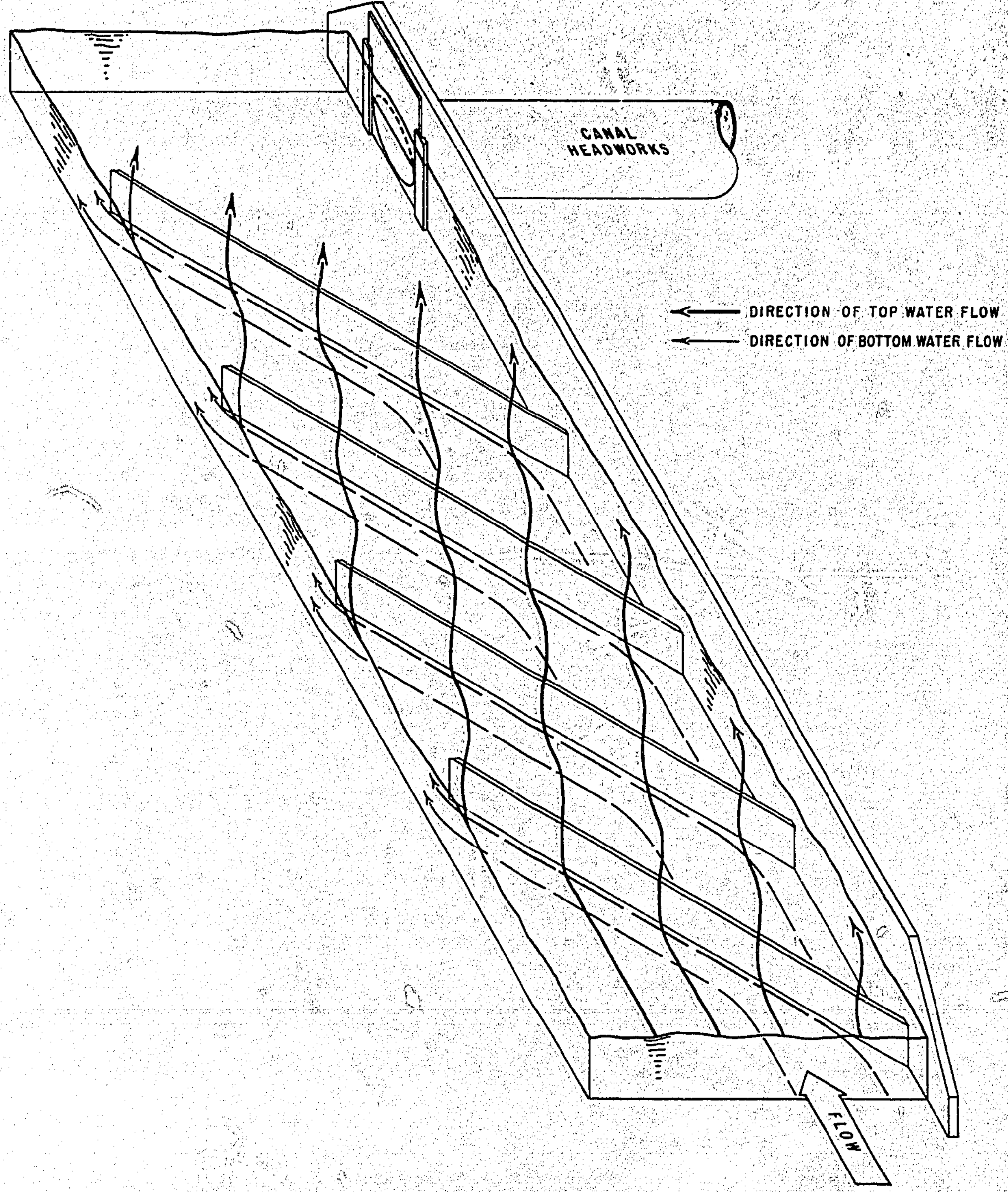


NOTE
Test 12 conducted without vanes - slab only in place

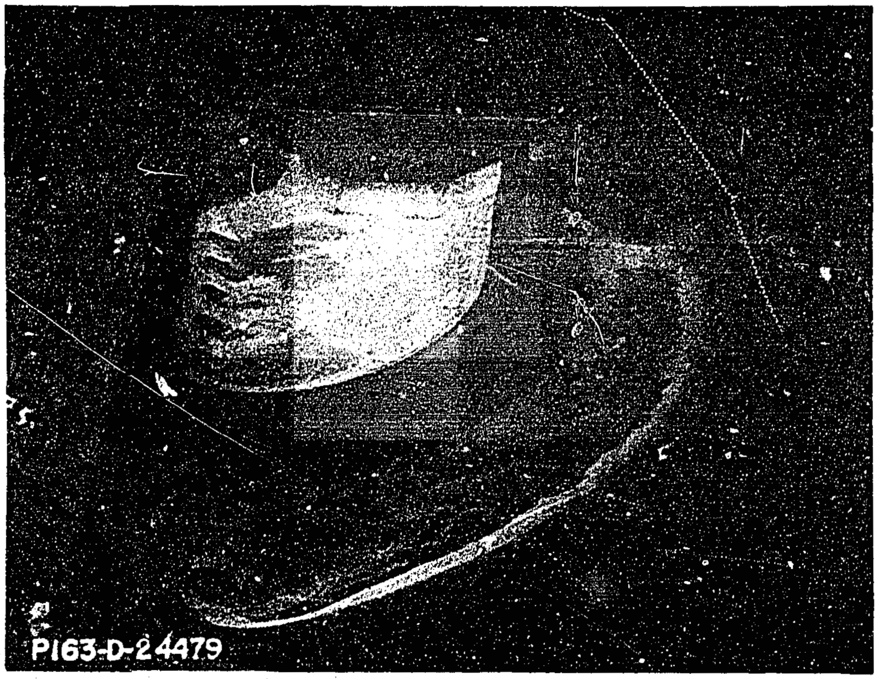
MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM

LOCATION OF BOTTOM GUIDE VANES
TEST 9-11, 13-27 AND 30

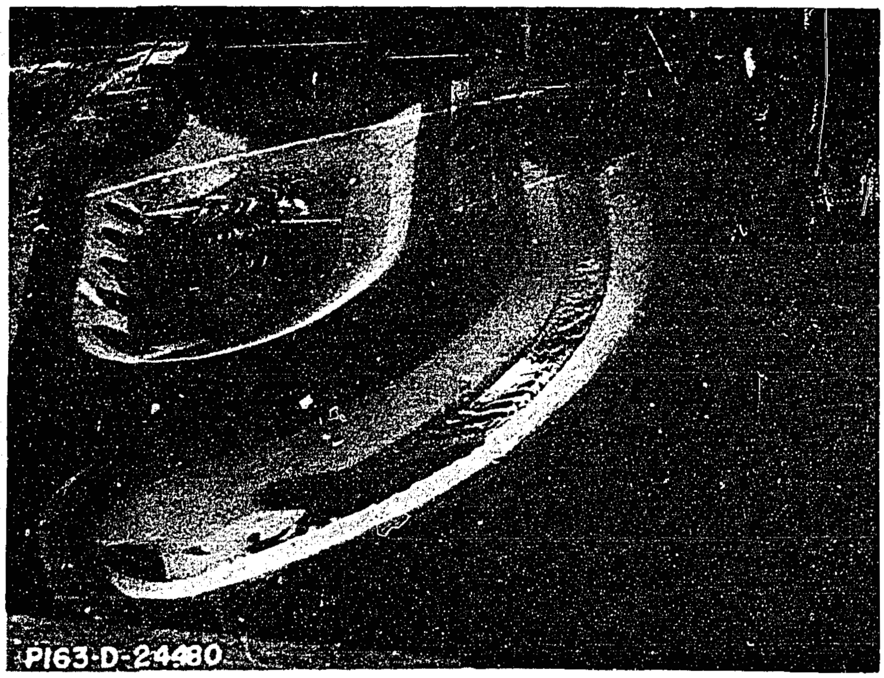
1:20 HYDRAULIC MODEL STUDY
(All dimensions shown are prototype)



MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM
BOTTOM GUIDE VANE METHOD OF PRODUCING SECONDARY
CURRENTS FOR SEDIMENT CONTROL AT SOCORRO MAIN CANAL HEADWORKS
1:20 HYDRAULIC MODEL STUDY



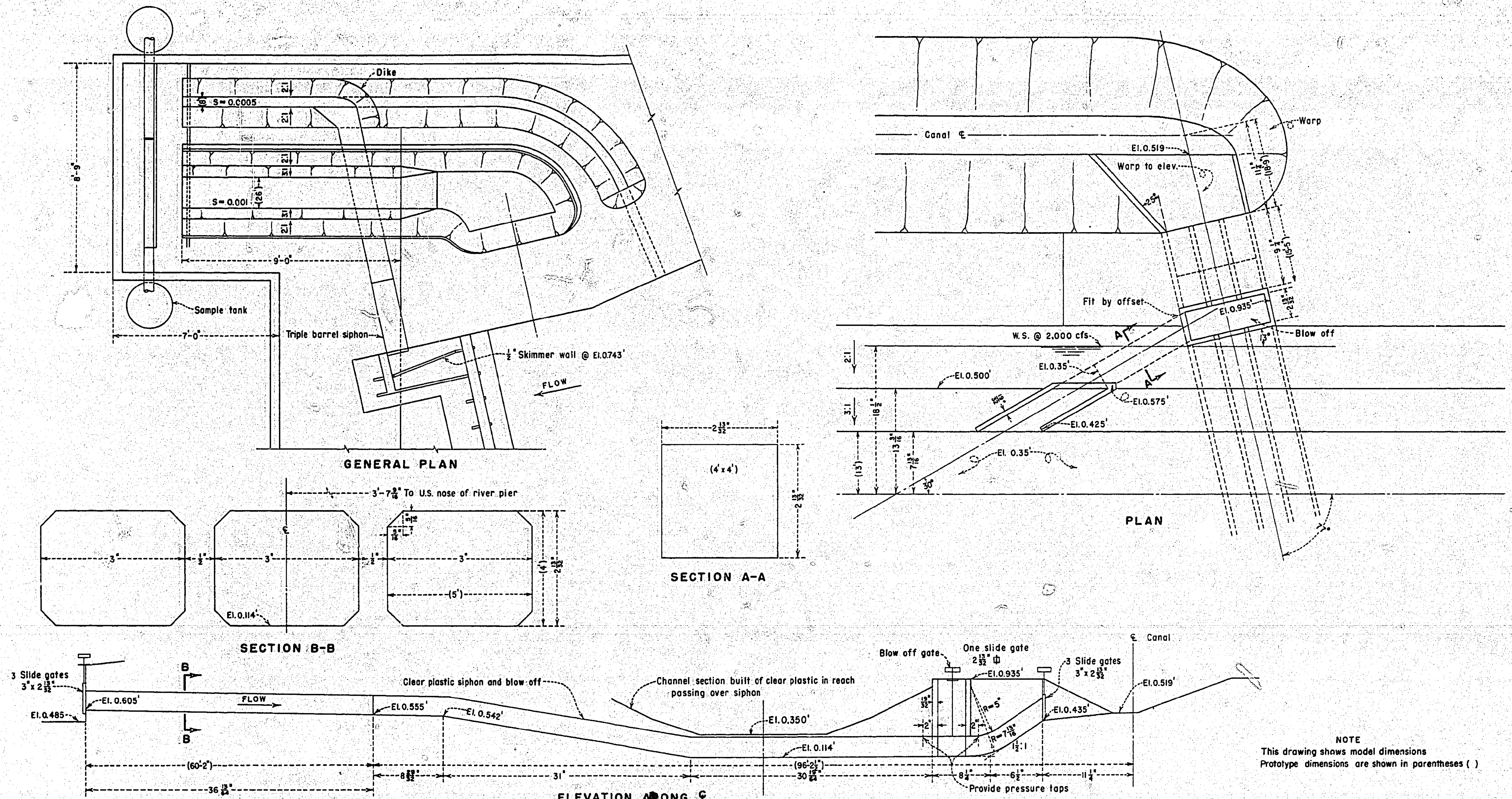
(a)
Without Bottom Guide Vanes



(b)
With Bottom Guide Vanes

MIDDLE RIO GRANDE PROJECT, NEW MEXICO
SAN ACACIA DIVERSION DAM
MODEL SEDIMENT DEPOSITS IN SOCORRO MAIN CANAL AND LOW FLOW CHANNEL WITHOUT AND WITH BOTTOM GUIDE VANES, PROTOTYPE CONDITIONS OF 1958, DISCHARGES WERE 680 C.F.S. IN RIVER, 200 C.F.S. IN CANAL, AND 480 C.F.S IN LOW FLOW CHANNEL

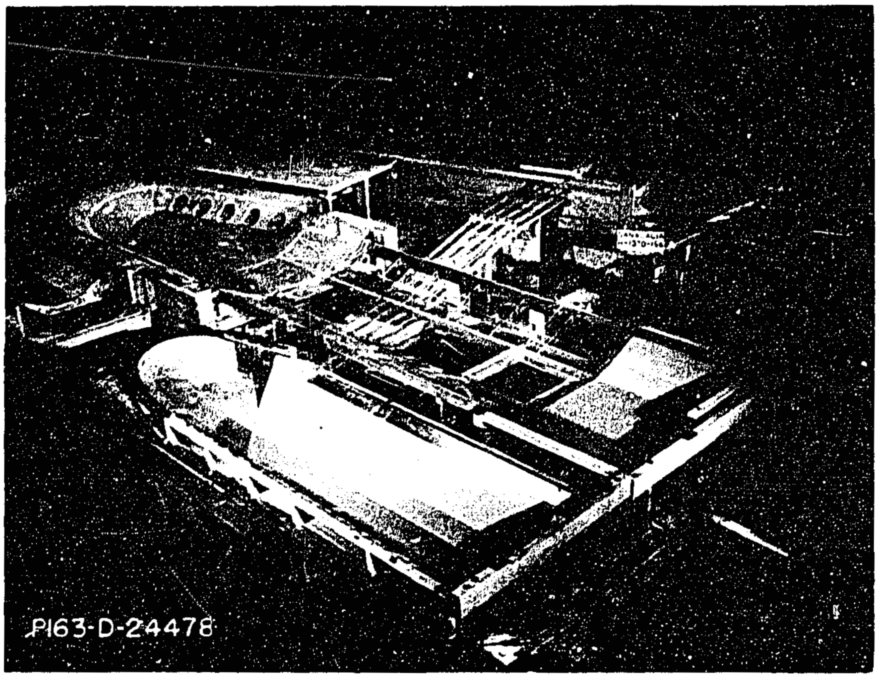
1:20 Hydraulic Model Study



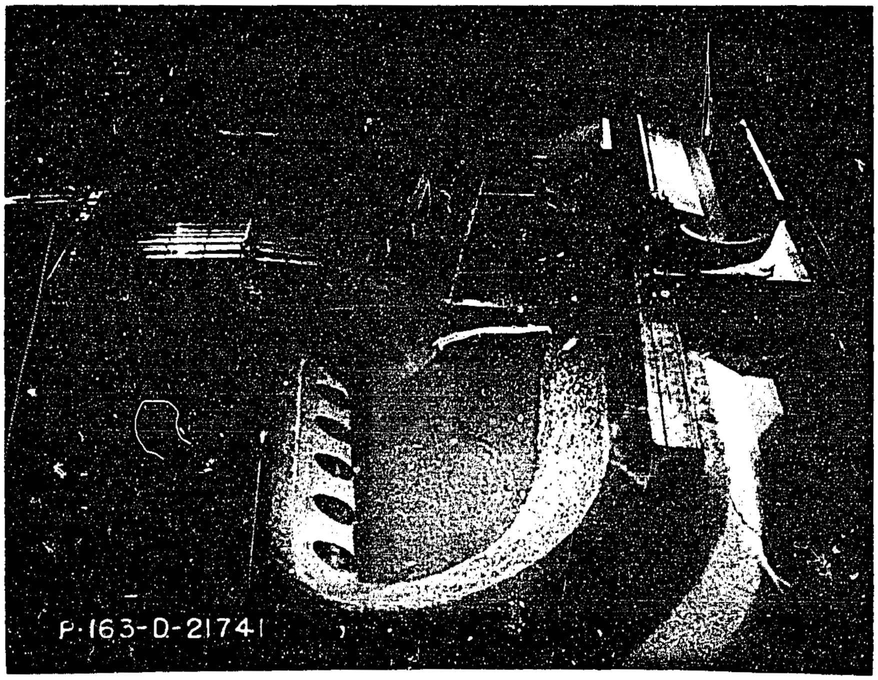
MIDDLE RIO GRANDE PROJECT – NEW MEXICO
SAN ACACIA DIVERSION DAM

SIPHON FROM CANAL HEADWORKS TO SOCORRO MAIN CANAL
PLAN AND SECTIONS

1:20 HYDRAULIC MODEL STUDY



(a)
Model Siphon Viewed from Right Bank of Canal



(b)
Model Siphon Looking Downstream from Near Low Flow Channel Headworks

Middle Rio Grande Project, New Mexico
San Acacia Diversion Dam
MODEL OF HEADWORKS WITH SIPHON TO SOCCORO MAIN CANAL

1:20 Hydraulic Model Study

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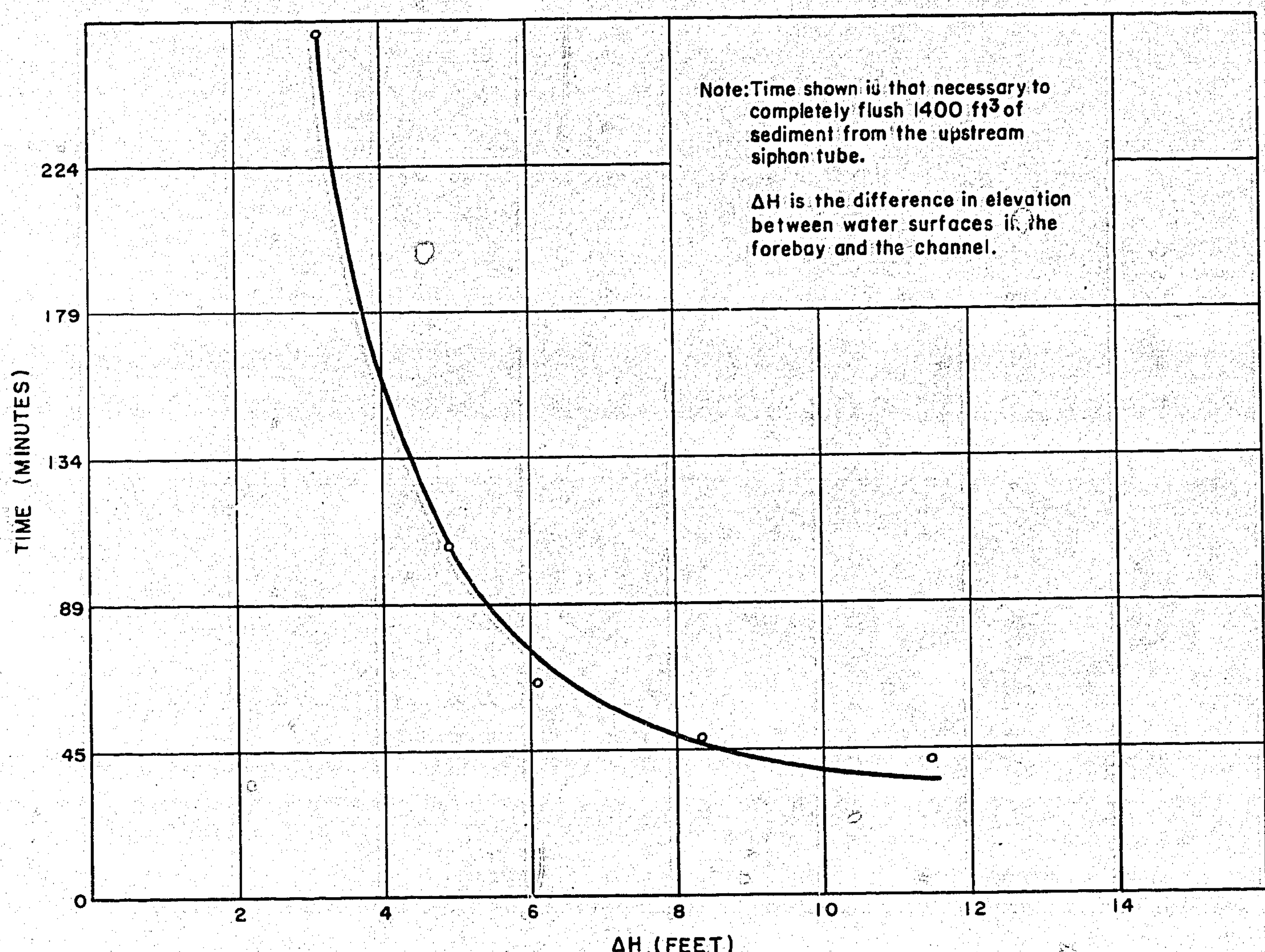
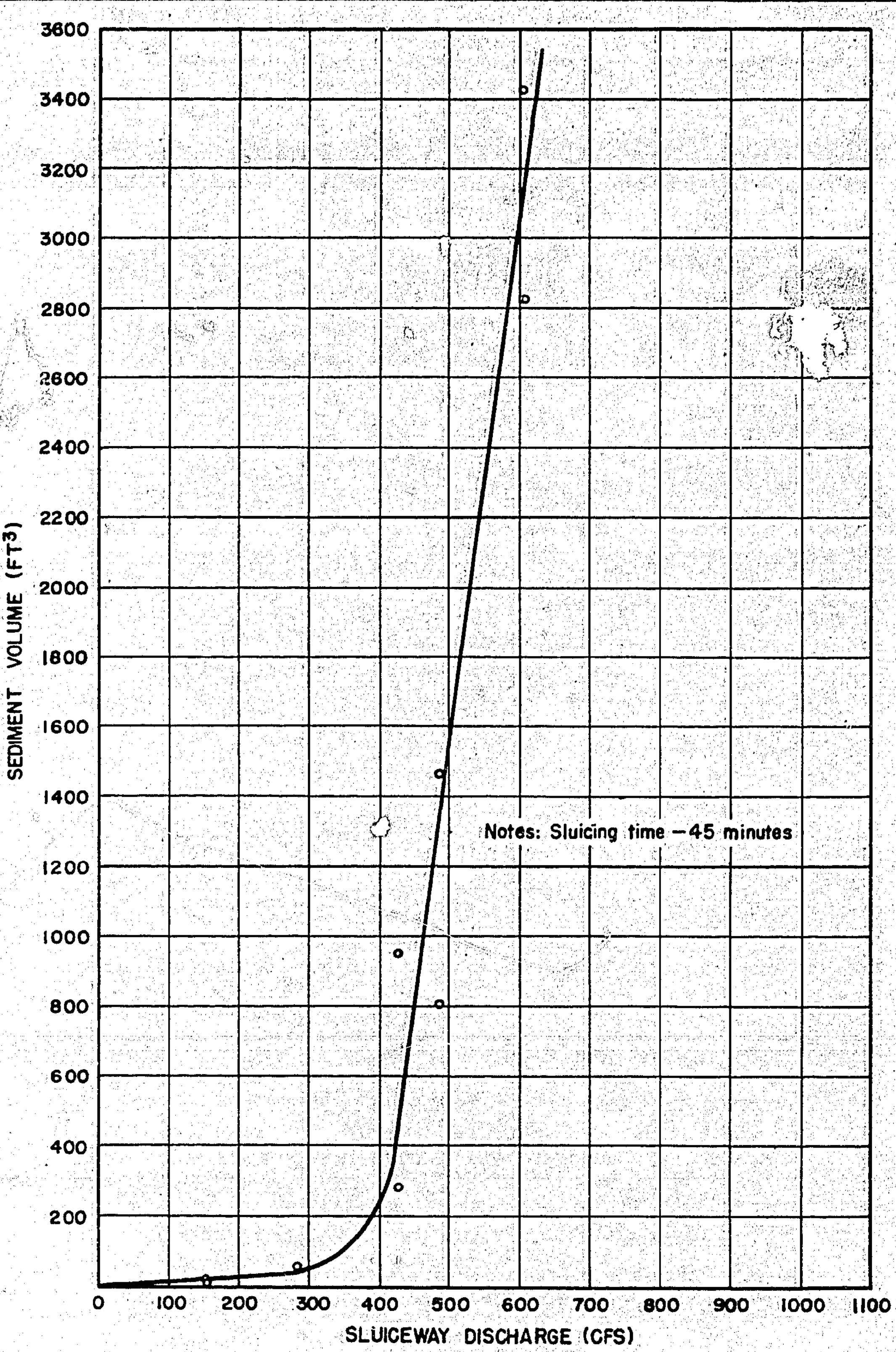


MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM
GRAPHIC RESULTS OF SLUICING SEDIMENT FROM SIPHON THROUGH BLOW-OFF
1:20 HYDRAULIC MODEL STUDY

FIGURE 17
HYD. REPORT 479



MIDDLE RIO GRANDE PROJECT–NEW MEXICO
SAN ACACIA DIVERSION DAM
GRAPHIC RESULTS OF SLUICING SEDIMENT FROM RIVER SLUICEWAY
1:20 HYDRAULIC MODEL STUDY

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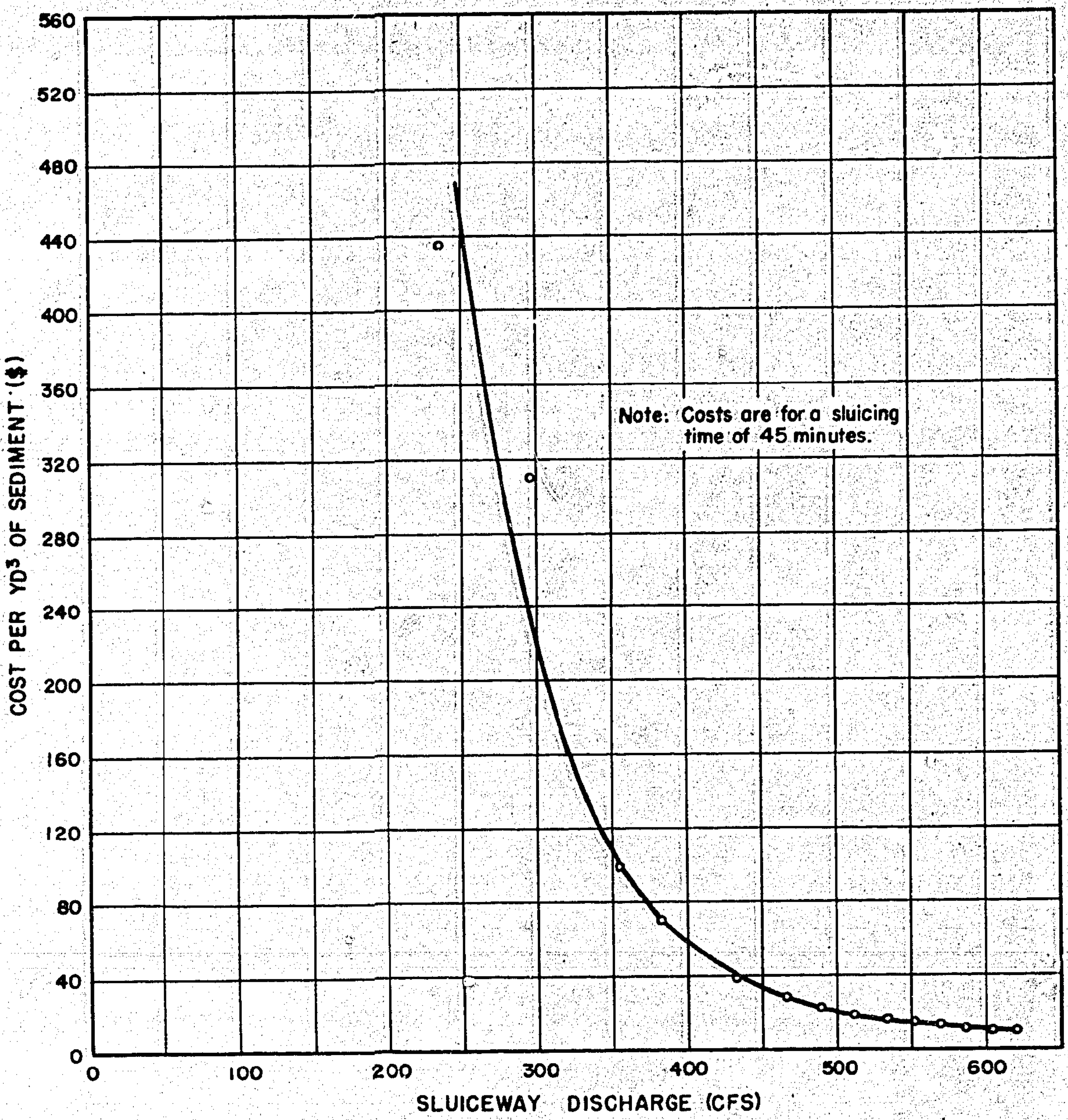
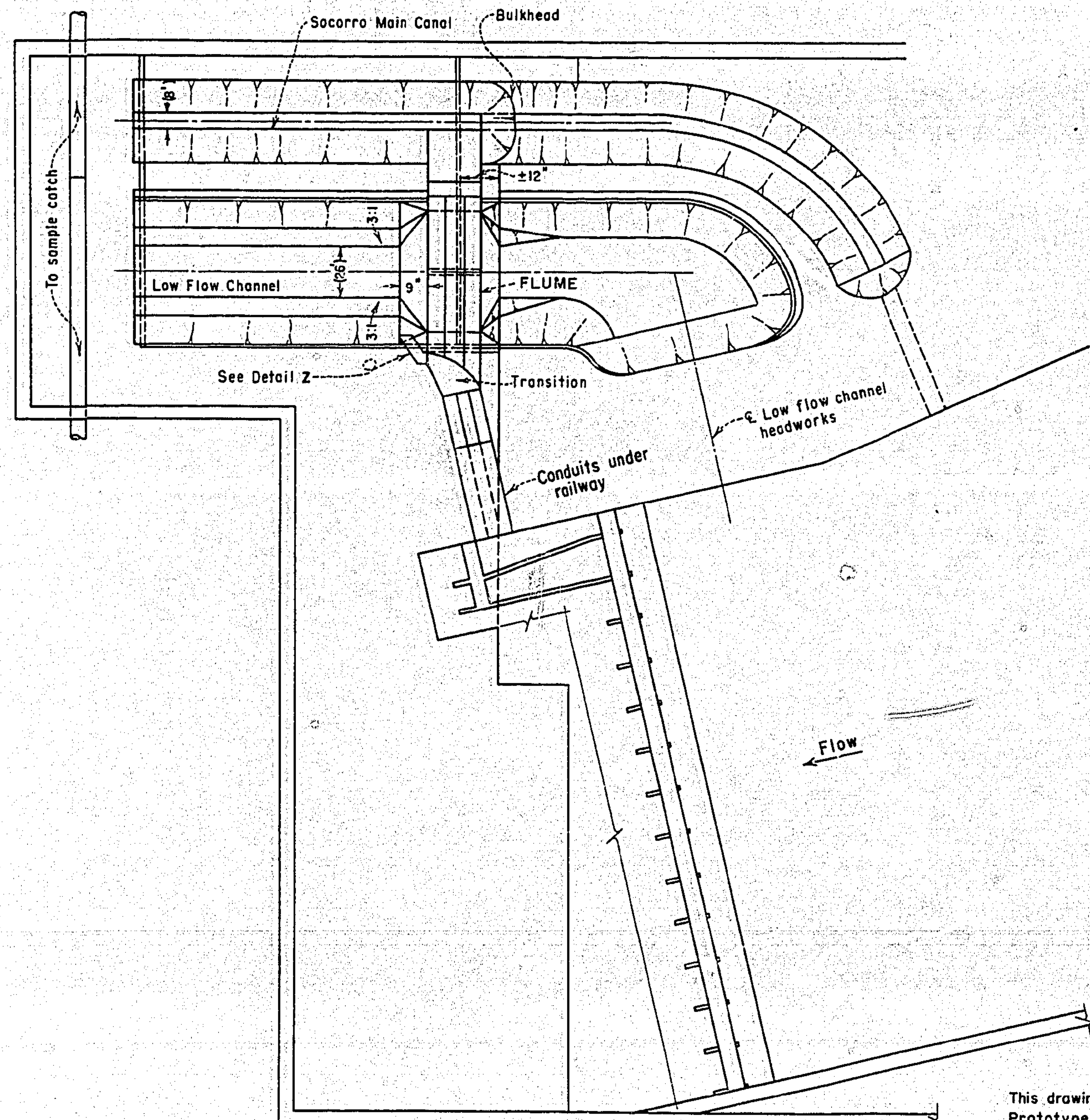


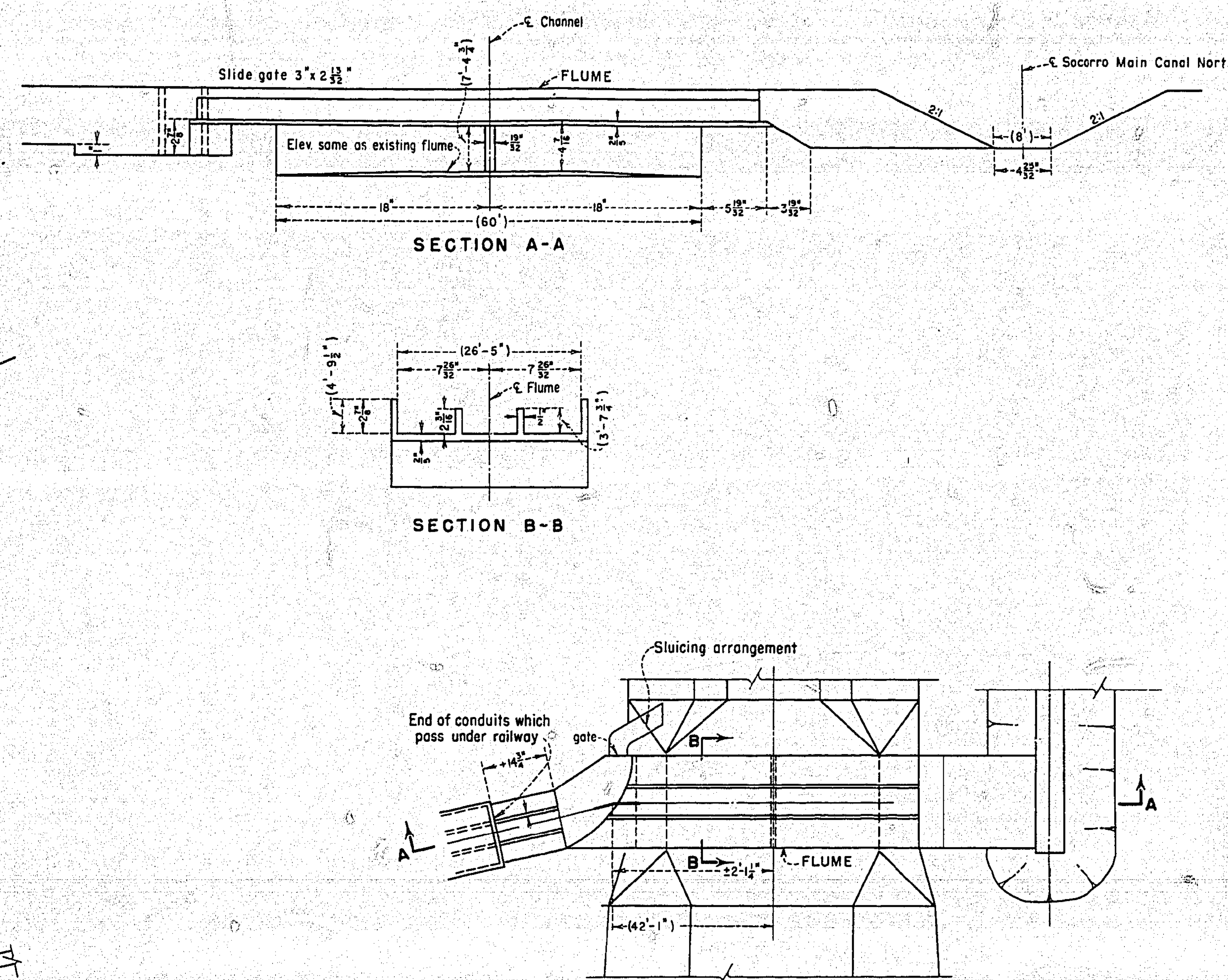
MIDDLE RIO GRANDE PROJECT-NEW MEXICO
SAN ACACIA DIVERSION DAM

GRAPHIC RESULTS SHOWING COST OF SLUICING SEDIMENT FROM RIVER SLUICEWAY

1:20 HYDRAULIC MODEL STUDY



PLAN



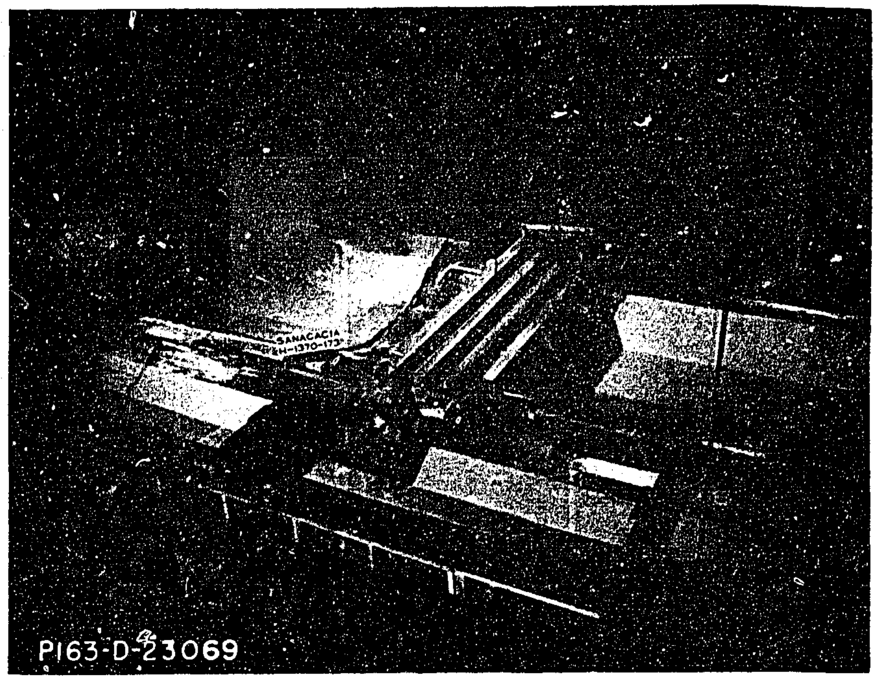
DETAIL Z

NOTE
This drawing shows model dimensions.
Prototype dimensions are shown in parentheses ( ).

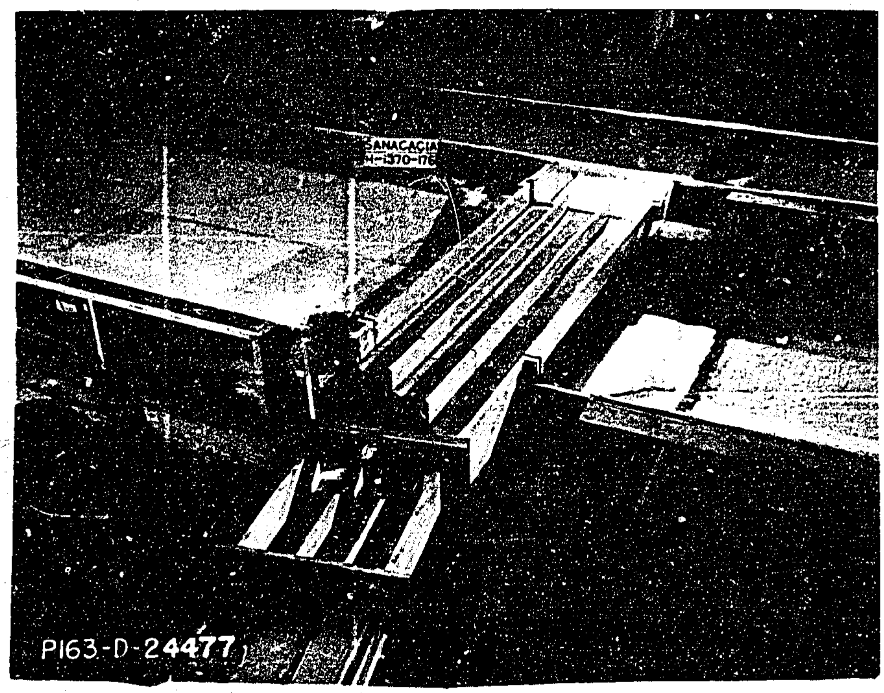
MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM

FLUME FROM CANAL HEADWORKS TO SOCORRO MAIN CANAL
PLAN AND SECTIONS

1:20 HYDRAULIC MODEL STUDY



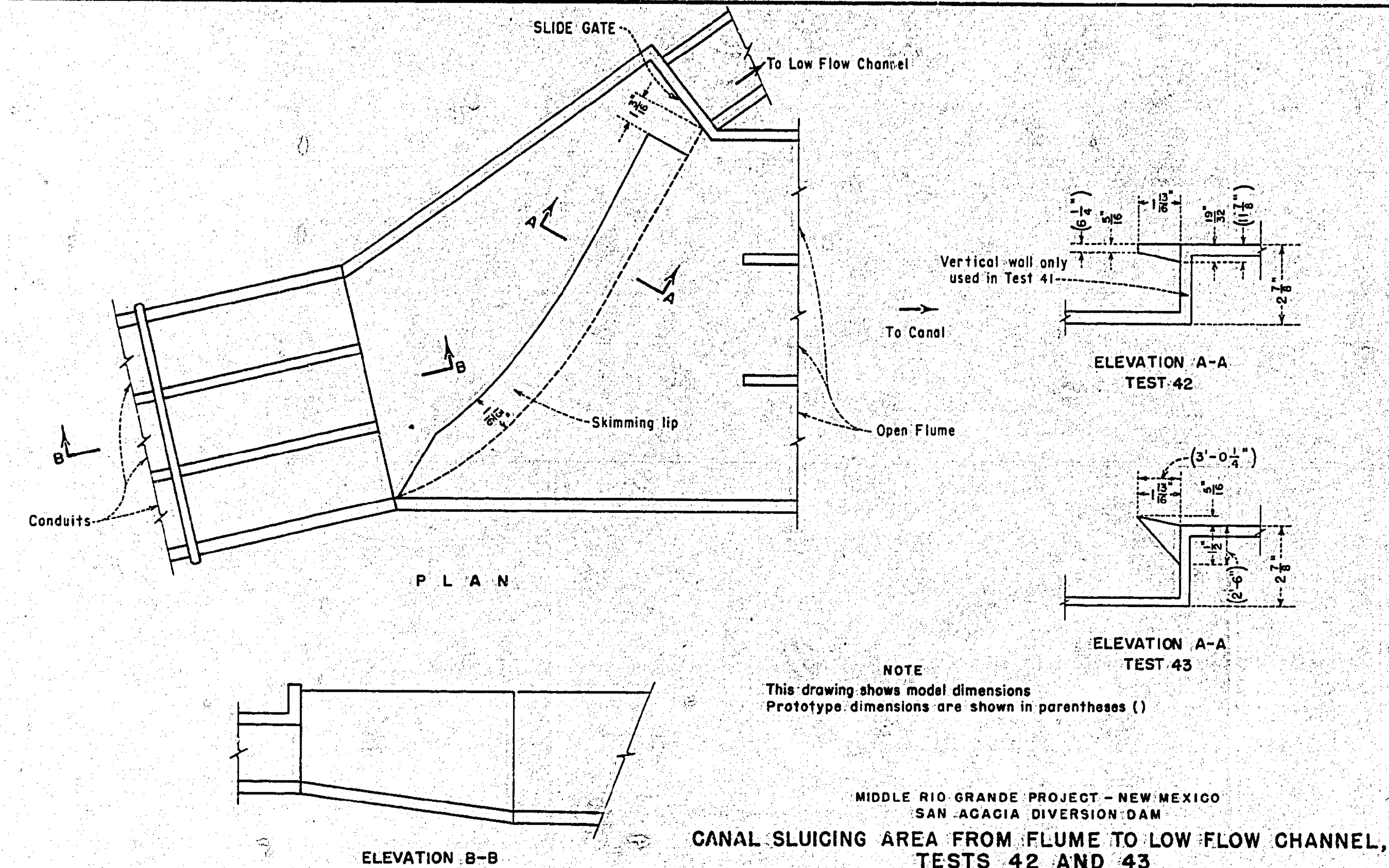
(a)
Model Flume Viewed from Right Bank of Canal



(b)
Model Flume Showing Sluice Area from Canal

Middle Rio Grande Project, New Mexico
San Acacia Diversion Dam
MODEL FLUME OVER CONVEYANCE CHANNEL

1:20 Hydraulic Model Study



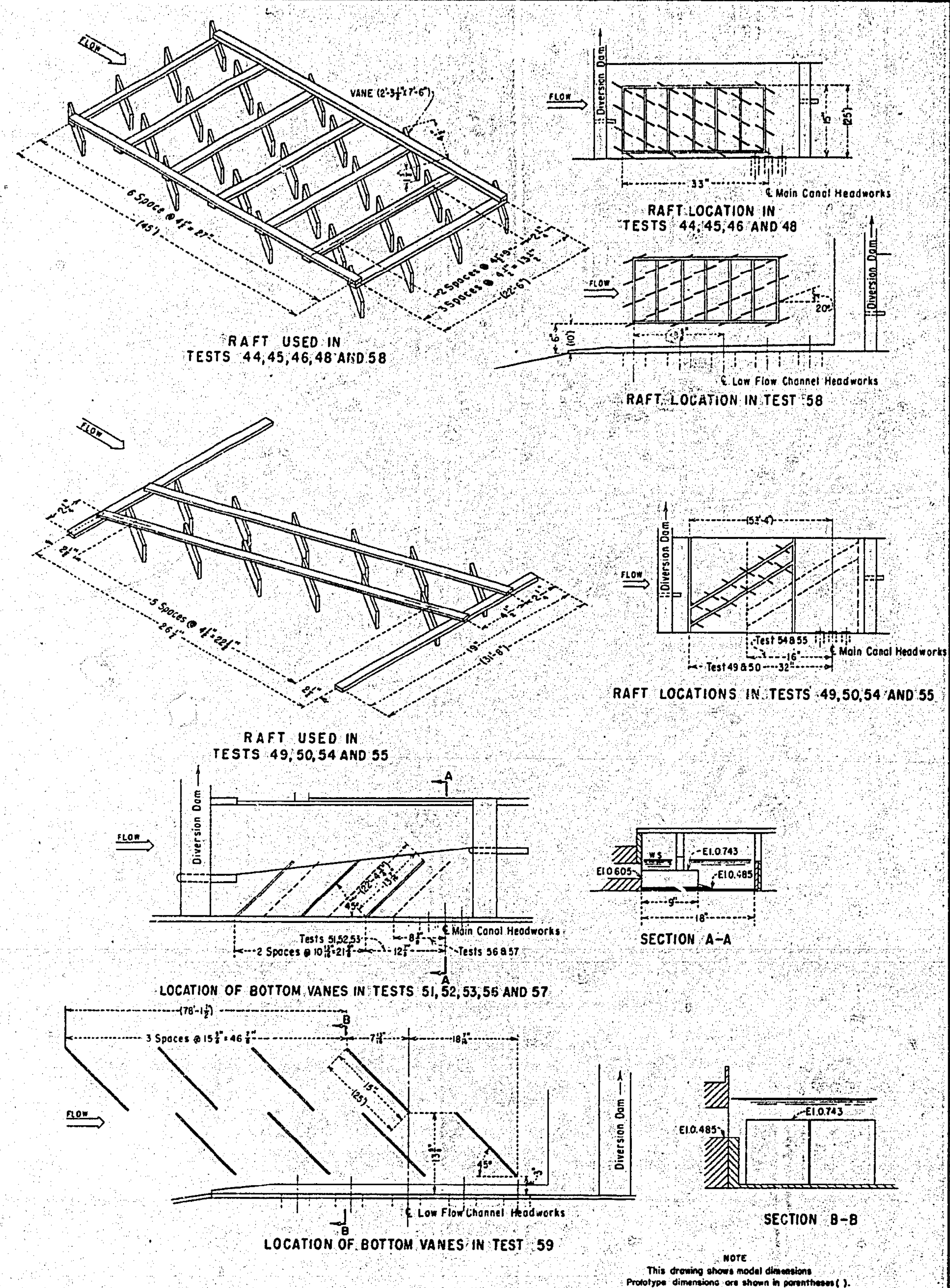
NOTE
This drawing shows model dimensions
Prototype dimensions are shown in parentheses ()

MIDDLE RIO GRANDE PROJECT - NEW MEXICO
SAN ACACIA DIVERSION DAM

CANAL SLUICING AREA FROM FLUME TO LOW FLOW CHANNEL, TESTS 42 AND 43

1:20 HYDRAULIC MODEL STUDY

FIGURE 22
HYD. REPORT 479



MIDDLE RIO GRANDE PROJECT – NEW MEXICO
SAN ACACIA DIVERSION DAM

FLOATING AND BOTTOM GUIDE VANES USED IN TESTS 44-46 AND 48-59

1:20 HYDRAULIC MODEL STUDY

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